Status Reports on Technical Studies for the Storage and Conveyance Refinement Process

Recalibration of the Delta Simulation Model I (Suisun Marsh Version)

FINAL REPORT
September 4, 1997

CALFED
BAY-DELTA
PROGRAM

State of California | The Resources Agency

Memorandum

Date : September 4 , 1997

To : Stein Buer, Chief
Technical Services Branch
CALFED Bay-Delta Program

Kamyar Guivetchi, Program Manager
Suisun Marsh Branch

From : Department of Water Resources

Subject: Recalibration of the Delta Simulation Model 1 (Suisun Marsh Version)

I have attached a final report prepared by the Suisun Marsh Branch on recalibration of the Delta Simulation Model 1 (Suisun Marsh Version) model. The report summarizes the geometry revision based on the latest Delta and Bay bathymetry data, and the DSM1 hydrodynamics and salinity recalibration based on the latest flow and salinity data. We plan to attend the September 24, 1997 Storage and Conveyance Workshop to answer any questions about the report.

If you have any questions or comments, please contact either Chris Enright at (916) 227-7521 or me at (916) 227-7529 or e-mail me at kamyarg@water.ca.gov.

Attachment

SURNAME	Christopher Enright 8-5-97 for Kamyar Guivetchi		
DWR 155 (Rev. 2/86)			

Recalibration of the Delta Simulation Model 1
(Suisun Marsh Version)

Suisun Marsh Branch
Environmental Services Office
Department of Water Resources
September 2, 1997

Table of Contents

I. Introduction

In November 1996, the CALFED Bay-Delta Program asked the DWR Suisun Marsh Branch to recalibrate the Delta Simulation Model in response to concerns that it was not adequately calibrated with available flow data. An effort to create a new public domain one-dimensional Delta model is ongoing within the Department of Water Resources. The purpose of the recalibration is to meet the concerns about DSM1, while, in coordination with the Interagency Ecological Program's Delta Model Project Work Team, continuing progress toward a new Delta model. As the need for modeling CALFED alternatives approached, it was intended that an evaluation of the available models would be made and the best available model would be used for programmatic EIR alternatives evaluation.

The Suisun Marsh Planning Section of the DWR Environmental Services Office has conducted modeling studies in support of DWR Suisun Marsh activities since 1990. In that time, significant experience using the DWR Delta Simulation Model has been accumulated. Major applications of the model for Suisun Marsh impact analysis include

- Western Suisun Marsh Salinity Control Project
- CUWA/AG rim hydrology impact analysis
- State Water Resources Control Board 1995 Water Quality Control Plan
- Updating the Suisun Marsh Preservation Agreement

In the course of these applications, major model enhancements were made to better account for seasonal water operations on the managed wetlands of Suisun Marsh, and to account for the effect of changes in Delta outflow on salinity in Suisun Bay. As a result, two versions of the Delta Simulation Model have emerged within the DWR: The Office of State Water Project Planning uses a version (DSM1) optimized for Sacramento-San Joaquin Delta planning, while the Environmental Services Office uses a version (DSM Suisun Marsh Version) optimized for Suisun Marsh planning and forecasting. A goal of the recalibration was to obtain improvements that are amenable to both versions.

II. Objectives

At the outset, the Suisun Marsh Planning Section identified five objectives for recalibrating the Delta Simulation Model.

1. Facilitate an open discussion by providing full disclosure of the calibration process and opportunities for comment from interested parties.
2. Update the model channel descriptions based on a recently developed bathymetry database.
3. Improve the flow calibration based on recent flow data collected by the US Geological Survey.
4. Improve the salinity transport calibration based on salinity monitoring data.

5. Merge calibration and geometry improvements to the Office of SWP Planning version of DSM1.

This report includes a discussion of each of these topics in turn. In addition, we have discussed limitations of the model, as well as limitations of the bathymetry and flow data. Finally, recommendations are made for further data collection and model development.

III. Outreach on Recalibration Progress

The catalyst for the recalibration effort originated primarily from agency personnel outside of DWR who are involved with numerical modeling of the Bay-Delta system. Since the intent of CALFED staff is to be responsive to the concerns of interested parties regarding the efficacy of analysis tools, an emphasis on outreach about recalibration methodology and progress was considered essential. Moreover, other modelers were able to provide expert assistance in planning recalibration methodology and assessing recalibration results.

It was also recognized that there is a wealth of modeling and field experience within the larger community of Bay-Delta scientists and engineers. By providing easy access to recalibration results and opportunities for constructive feedback, we believe that tha outcome of this effort is improved.

In general, a level of confidence was established among all interested persons, modelers and non-modelers alike, in the ability of the recalibrated mode to provide reasonably accurate results for evaluation of proposed alternatives. By providing an open atmosphere for monitoring and feedback, the credibility of the recalibration process was enhanced.

Outreach for the DSM1 recalibration was specifically accomplished using three approaches: 1) an ad hoc multi-agency recalibration team, 2) an email reflector, and 3) a world wide web site.

1. **<u>Ad Hoc Recalibration Team</u>** On January 10, 1997, an *ad hoc* committee of interagency personnel was convened to provide review and input to the preliminary recalibration design. Comments were received on available data sources, optimal calibration periods, geometry revision methodology, calibration approach, and output formats.

2. **<u>Recalibration Electronic Mail Reflector</u>** An electronic mail reflector was created to facilitate updates and open discussion of recalibration issues and progress. The intent was to provide a tool by which questions and concerns about any aspect of the recalibration could be aired conveniently among those subscribed to the reflector list. Members of the *ad hoc* committee and some CALFED staff were initially included and other were invited to subscribe. The email reflector is still active, and can be accessed by sending email to "*dsm1cal.water.ca.gov*."

3. **World Wide Web Page** All recalibration progress was shared, in near real-time, through a world wide web site connected to the Interagency Ecological Program (IEP) home page (*www.iep.water.ca.gov*). Maintenance of the web site was a joint effort of IEP File Server staff and DWR staff. The web site (Figure 1) includes links to the following information:

   - DSM1 hydrodynamics recalibration plots and meta data
   - DSM1 salinity recalibration plots and meta data
   - Manning's n and dispersion coefficient groups (map)
   - Three-Mile Slough bathymetry data
   - Background documents

   Over three-thousand plots of field data and model flow, stage, and salinity results are available for viewing in time sequenced order. Each run includes a meta data file which documents the incremental changes to calibration parameters and geometry descriptions. Plots and meta data are arranged by calibration run number and are available for downloading in "gif" and "postscript" formats. Taken together, the plots and meta files represent a complete history of the recalibration process.

IV. DSM1 Geometry Revision

The objective of the geometry revision project was to update Delta, Suisun Marsh, Suisun Bay and San Francisco Bay channel geometry descriptions by applying a systematic approach and using the best available bathymetry data. This section includes a discussion of the geometry revision methodology, pre and post revision geometry statistics, development of a geometry data base, and application of the new geometry to the Suisun Marsh version of DSM1.

A. Background

Prior to the geometry revision, the DSM1 channel geometry was determined primarily from National Oceanographic and Atmospheric Administration (NOAA) navigation charts which contain scattered point estimates of channel depth relative to local mean lower low water level. Limited field cross-section data was also used. It has long been suspected that the overall volume of the Delta represented by the previous geometry could be significantly in error. Further, evidence was building within the Bay-Delta modeling community that model performance could be improved with increased geometry accuracy.

In response to the perceived need, the DWR Modeling Support Branch developed a bathymetry database from sources of channel bathymetry data including DWR, USGS, NOAA, and the US Army Corps of Engineers (USCOE). All data were identified by source agency and year of collection, and converted to a common horizontal (UTM Zone 10) and vertical (NGVD, Golden Gate) datum. In addition, a contract was let to a private consultant to create a Bathymetry Data Display software package (BDD) capable of providing plan and down-channel views of the data, along with measurements of channel characteristics including segment length, cross-section area, top-width, wetted perimeter, and volume. The bathymetry database, and the BDD program were used extensively in the geometry revision process.

B. Geometry Revision Methodology

The DSM1 model is limited to uniform rectangular channel cross-section characteristics along the length of any given channel. The goal of the geometry revision was to translate point bathymetry data for a given reach to a rectangular channel with the same volume and conveyance characteristics.

Specifically, DSM1 requires length, top-width, and depth for each of over six-hundred channels in the DSM1 grid (Figure 2). Since an average channel depth is a difficult quantity to measure from the point database, we relied on channel characteristics which can be measured with more certainty. Characteristics measured include centerline channel length (L) , mean lower low water cross-section area (A), top-width (T), and wetted perimeter (P). The DSM1 code was modified to read these data and then calculate a hydraulic depth (H_0) as area divided by top-width (A/T). Using this ratio normalizes depth for conveyance purposes, and provides a systematic way to calculate it.

After consulting with USGS staff, and conducting extensive experimentation to identify a systematic approach, the following general steps for revising the DSM1 channel bathymetry database using the BDD program were used.

1. Use BDD to orient a working plan view of the channel reach of interest (Figure 4A)
2. Interactively draw a channel thalweg the length of the reach using the mouse. View the channel profile to identify natural breaks in the cross-section. Record channel length.
3. Using the BDD cross-section viewing utility, investigate several cross-sections along the reach and identify representative sections.
4. Interactively draw a cross-section through the point bathymetry data. Record resulting top-width, wetted perimeter, cross-section area, and mean side slope (Figure 4B).
5. Identify completed cross-sections with DSM1 channel grid numbers.
6. Document each cross-section by saving bit maps and cross-section characteristics data.

Figure 3 includes a flowchart which is part of the Geometry revision documentation.

C. Highlights of Geometry Changes

Table 1 shows a summary of DSM1 channel geometry statistics. Both pre and post revision geometry statistics are shown. The number of channels was increased by twenty-four, most notably by adding channels in the vicinity of the Sacramento-San Joaquin river confluence to account for deep channels and wide, shallow shoals in the same reach. Additionally, some channels were added by re-casting open water areas in Suisun Bay as hubs of wide, shallow channels. Open water areas were previously treated as numerical tanks with questionable transport characteristics.

A total of 558 channels were revised by virtually "surveying" over 1000 cross-sections. The total length of channels in the DSM1 grid remained nearly the same, but the total volume of the system below NGVD mean lower low water was reduced by about 22%.

Figure 5 shows the Delta and Suisun Bay distribution of volume changes. A more accurate method for determining the surface area of channels was employed in San Francisco Bay resulting in a volume reduction of about 26%. Channel volumes were also reduced in the Sacramento River, San Joaquin River, the South Delta, Suisun Marsh, and Suisun Bay. In general, channel depth was reduced by calculating it as hydraulic depth (A/T). Volume increased by 10% in Carquinez Straight and 7% in the North Delta from the previous geometry.

D. Geometry Revision Documentation

While the geometry revision project is considered fundamental to the success of the DSM1 recalibration effort, it is also a valuable product in its own right. It represents the culmination of efforts by the DWR Modeling Support Branch and Suisun Marsh Planning Section to organize and integrate over four-hundred thousand data points from multiple agencies into a consistent format, to develop specialized software making it possible to analyze and manipulate the data, and to represent the field bathymetry data as cross-sections amenable to DSM1 model input. The results are useful beyond DSM1 to other activities requiring Bay-Delta channel geometry information. As such, a stand alone documentation of the geometry revision has been prepared and is available upon request. The documentation is provided on CD ROM media, and includes (Figure 6):

- Written and graphical documentation
- Bathymetry view software (BDD) for the PC
- The complete bathymetry data set in horizontal UTM and vertical NGVD coordinates
- Digitally "surveyed" cross-sections including bit-maps and tabular channel characteristics
- A copy of the previous DSM1 Suisun Marsh Version geometry (GI.G8A) for reference and comparison
- A copy of the revised DSM1 Suisun Marsh Version geometry file (GI.G9A) which includes updated channel parameters and calibration coefficients.
- An up-to-date copy of the DSM1 Suisun Marsh Version grid map

Requests for copies of the geometry revision documentation can be made to

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V. DSM1 Suisun Marsh Version Hydrodynamics Recalibration

This project was motivated by a growing concern that the DSM1 model was not adequately calibrated with recently available flow data collected by the US Geological Survey. As such, this section reports on the heart of the overall recalibration project. The section includes:

- Rationale for hydrodynamics calibration periods
- Calibration approach
- Calibration strategy
- Results and discussion

A. Hydrodynamics Calibration Periods

The primary goal in the choice of hydrodynamics calibration periods was to exercise the model under a range of flows and structural/operational conditions. A constraint on choosing the calibration period was the need to match the periods to times when flow data were available. Three historical periods of ten to fourteen days in May 1988, January 1993, and May 1994 were chosen for the hydrodynamics calibration. The three periods represent a diversity of rim flow hydrologies, structural configurations, and operational scenarios. The following is a summary of flow data availability and the hydrologic/structural conditions associated with each calibration period.

1. May 9-21 1988:
    - Twelve to sixteen hours of flow data are available for thirteen Delta locations. Continuous flow data are available for two stations.
    - CVP and SWP exports averaged 6,500 cfs; Sacramento River flow was approximately 12,000 cfs; Net Delta Outflow Index ranged between 3,000 and 6,000 cfs

2. January 10-21 1993:
    - Continuous flow data are available for Old River (USGS Ultrasonic Velocity Meter [UVM]), Middle River (UVM), Sacramento River above the Delta Cross Channel, Sacramento River below Georgiana Slough, and Georgiana Slough
    - San Joaquin River flow increased from 2,000 to 10,000 cfs
    - Sacramento River flow increased from 38,000 to 80,000 cfs
    - State Water Project pump test was being conducted between January 16-21 (up to 10,600 cfs SWP pumping)
    - Delta Cross Channel was closed
    - Full-bore Suisun Marsh Salinity Control Gate (SMSCG) tidal pumping operation

3. May 15 - June 1, 1994:
    - Continuous flow data are available at Old River (USGS UVM), Middle River (USGS UVM), the Sacramento River above the Delta Cross Channel, the Sacramento River below Georgiana Slough, Jersey Point, and Three Mile Slough.

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- Sacramento River flow was approximately 8,000 cfs; exports ranged between 1,500 and 2,800 cfs; Net Delta Outflow Index was approximately 3,500 cfs.
- Temporary agricultural barriers were installed in Middle River at Victoria Island and Old River near the Delta Mendota Canal

B. Hydrodynamics Calibration Approach

In it's simplest form, the calibration process attempts to match model flow, velocity, and water level time-series output to field data. For each calibration period, the known historical Golden Gate boundary tide, river inflows, agricultural depletions, precipitation, water project exports, and structural configurations are input to the model. Repeated model runs are made with incremental adjustments to model coefficients controlling the magnitude of channel friction until an adequate match between field and model flow, velocity and water level data is achieved in the interior of the system.

The hydrodynamics calibration parameter is called Manning's n which accounts for channel bed friction under conditions of uniform flow. The equations underlying the DSM1 model allow for non-uniform, unsteady flows. Therefore, lumped into Manning's n are all physical factors not explicitly included in the governing equations, along with all errors in the geometrical description of the system, and all errors in the input hydrology and structural configuration data. An example of physical factors not included in the equations is the baroclinic pressure gradient between regions of relatively salty and fresh water. An example of errors in the geometrical description of the system is the requirement for cross-section uniformity along the length of each channel in the model grid. Finally, input data errors are exemplified by the uncertain nature of agricultural diversion and drainage magnitude, timing, and distribution.

A separate value of Manning's n can be assigned to each of the 642 channels in the DSM1 grid. As a practical matter, it was necessary to assume that channels with similar characteristics can be lumped together. To initiate the calibration, the same Manning's n value was assigned to each channel within eighteen Delta and Bay regions which were delineated by similarity of channel characteristics. For example, the Sacramento River channels between Sacramento and Walnut Grove were grouped together because they share similar cross-section characteristics. Figure 7 shows the Suisun Bay and Delta portions of the channel groupings at the end of the calibration when forty-three channel groups were being used.

Over fifty hydrodynamics calibration runs were conducted. To organize and document the process, an automated input system was developed. Manning's n changes in a given group were made in a "meta file" to centralize and simplify the procedure. The meta file was in turn used as input to a preprocessing program which automatically modified the directory structure, moved files, generated a run-time batch file, and distributed the group Manning's n changes to the member channels of the group. The meta file also included space for logging the run number, date, and changes made in each run. This provided a living history and complete documentation of the decisions made during the calibration. Figure 8 shows an example meta file.

C. Hydrodynamics Calibration Strategy

Experience with hydrodynamics model calibrations in the past has shown that flexibility in the approach to coefficient adjustment is essential as the behavior of the model unfolds. Therefore, at the outset, we were interested is determining the sensitivity of the model to rather gross changes in friction coefficients. The first three calibration runs investigated three levels of Manning's n applied as a constant over the entire domain. The most promising of the three was considered the starting point for the calibration.

The next several runs investigated the relative power of Manning's n to affect the phasing of the tidal boundary wave at key downstream locations like Carquinez Straight. On the expectation that the bathymetry data is somewhat in error, we also investigated the effect of slight increases in San Francisco Bay depth to move the tidal wave more rapidly. Several iterations were required to achieve accurate tidal phasing into Suisun Bay while maintaining tidal amplitudes near field data levels.

In general, the calibration proceeded from the west (the Pacific Ocean boundary at the Golden Gate) to the east into the Delta and up the Sacramento and San Joaquin rivers. The goal was to propagate tidal energy, as represented by wave phasing and amplitude, as accurately as possible. Of particular importance, upon entering the Delta, was balancing the division of tidal energy between the lower San Joaquin and Sacramento River. In this regard, the intervening influence of the connecting channels, Broad Slough, Sherman Lake, and Three Mile Slough was evident.

D. Hydrodynamics Calibration Output

Decisions about how to proceed at each step of the calibration were made by visual comparison of 15-minute time-series field data and model output for 27 flow and 42 stage monitoring locations. In addition, scatter plots of field versus model stage were produced along with regression statistics as a systematic measure of goodness-of-fit. Finally, 24.75 hour average flows for locations with continuous field flow data were produced.

To facilitate assessment of the progress of the calibration, each time-series flow and stage plot contains three traces: 1) the current "best" run result, 2) the latest run result, and 3) the field data. The output for each run includes:

- 3 periods
- 27 time-series flow monitoring locations
- 42 time-series stage monitoring locations
- 3 potential pieces of data on each plot
- 42 stage scatter/regression plots

- total of 296 plots
- total of 1013 potential data streams

- rendered on 30 pages
- 24.75 hour average flows were produced for some runs
- "acceleration index" plots were produced for some runs

All results are available for viewing on the web site described in Section III.

E. Hydrodynamics Calibration Results

Figures 9 through 13 exhibit the final hydrodynamics calibration results for the May 1988 calibration period. Geographically similar flow and stage output locations are generally grouped on the same page. The calibration web site contains plots for all three calibration periods and all calibration trials. The same ordering of output locations is used for each period to facilitate comparison across periods. Flow and stage information for the same location are grouped in consecutive panels.

Figures 14 through 16 exhibit example stage scatter plots for the May 1988 calibration period. The 1:1 line is shown, along with regression statistics. Figure 17 shows example 24.75 hour running average flow field data and model results. Figure 18 shows an example "acceleration index" result, obtained by taking the derivative of flow with respect to time to recover the time rate of change of the flow sequence.

F. Observations

Many trends and tendencies were observed during the course of the recalibration. Some key observations are offered here, and the DSM1 calibration email reflector is available for additional observations or comments.

Datum Shifting The datum for much of the stage data is shifted in the upward direction indicating gage settling. For this reason, the calibration did not emphasize datum matching. This also suggests that vertical control in the geometry data is not particularly reliable.

Three Mile Slough and other Sacramento-San Joaquin River Connections. Three Mile Slough has long been considered a key hydrodynamic connection between the lower Sacramento and San Joaquin Rivers yet there is little specific understanding of how it works. It conducts high tidal flows especially on flood tides because the flood wave arrives sooner at the Sacramento side than the San Joaquin side. This exchange of tidal flow on the flood tide accounts for most of the net flux of water from the Sacramento to the San Joaquin river through Three Mile Slough.

Similarly, Sherman Lake and Broad Slough play an unknown but likely important role in Sacramento-San Joaquin River hydrodynamic connectivity. However, bathymetry information is uncertain for either area and little is known about the geometry of Sherman Lake river connections. Several sensitivity runs indicated that modifications to Sherman Lake and Broad Slough bathymetry has a significant effect on regional flow patterns.

Model Output Feedback to Geometry Data The geometry revision process improved the accuracy of channel descriptions in the model. With this enhanced accuracy, a useful feedback between model flow predictions and geometry is now available. On a few occasions, we noticed anomalous differences between field flow and stage data in specific locations as compared to the model. These differences flagged the need to revisit the geometry revision for that location where a geometry analysis error was usually revealed. At the same time, anomalies that could not be explained by closer examination of the geometry revision may suggest errors in the geometry data. Geometry data errors are to be expected considering that channel beds change with time, and much of the data is outdated. The model can therefore identify areas where future bathymetry data collection efforts should be concentrated.

VI. Recalibration of the DSM1 Salinity Module

The main focus of the recalibration effort was to improve the hydrodynamics response of the DSM1 model using the latest USGS flow data. Since the salinity transport capability of the model is part and parcel of the flow field response, the transport coefficients of the model also required adjustment. Transport of conservative constituents like salt is conceptually controlled by two factors: advection and dispersion. Advection accounts for that portion of salt transport controlled by the average velocity field. Dispersion lumps all other factors which cause salt transport to deviate from the average velocity field of the one dimensional model. Deviations are caused by variability of the velocity field from average in the lateral and vertical directions within a cross-section which results in turbulent mixing. Calibration of salinity transport focuses on adjusting mixing due to cross-section velocity field variability.

The section includes:

- Salinity calibration period
- Salinity calibration approach
- Salinity calibration strategy
- Results and discussion

A. Salinity Calibration Period

The salinity calibration period is water years 1992 through 1994. Since transport model calibrations require a known salinity throughout the model domain, a "warm-up" period is required to mix in known salinity boundary conditions to generate a reliable salinity field over the modeled system. The months between October 1991 and February 1992, when the first significant rain and runoff began, are considered the model warm-up period.

The calibration period includes a wet year (1993) bracketed by two dry years (1992 and 1994). This sequence presents the model with a wide range of hydrologies and antecendent conditions.

B. Salinity Calibration Approach
As in the hydrodynamics calibration, each of the over 600 channels in the system is assigned a dispersion coefficient. As a practical matter, it was again necessary to assume that channels with similar characteristics can be lumped together. We used the same 43 channel groupings as developed for the hydrodynamics calibration (Figure 7).

Field salinity data are collected in units of specific conductance and were converted to units of total dissolved solids (TDS) using location specific conversion equations (DWR, 1986). TDS units are used for all model input and output.

Comparisons to field data were made on the basis of tidal day average 25 hour salinity.

Over sixty salinity calibration runs were conducted. The automated input system used for the hydrodynamics calibration was adapted to organize and document the process. Dispersion coefficient changes in a given group were made in a "meta file," and the meta file was in turn used as input to a preprocessing program which automatically modified the directory structure, moved files, generated a run-time batch file, and distributed the group dispersion coefficient changes to the member channels of the group. The meta file was also used to log the run number, date, and changes made for each run.

C. Salinity Calibration Strategy
As before, we were interested in determining the sensitivity of the model to large changes in dispersion coefficients. The first three calibration runs investigated three levels of dispersion coefficients applied as a constant over the entire model grid. The most promising of the three provided the starting point for the salinity calibration.

The goal was to mix salt into the system as accurately as possible. As in the hydrodynamics calibration, the salinity calibration proceeded from the west (the Pacific Ocean boundary at the Golden Gate) to the east into the Delta and up the Sacramento and San Joaquin rivers.

D. Salinity Calibration Output
Decisions about how to proceed at each step of the salinity calibration were made by visual comparison of 1-hour time-series field and model output for 43 salinity monitoring locations.

E. Salinity Calibration Results
Figures 19 through 23 show tidal-day average salinity time-series output. Three traces are represented on each plot: The dashed trace shows tidal day average salinity for the previous calibration run, the solid trace represents tidal day average salinity for the final calibration run, and the dotted line represents the field salinity data. The plots are arranged as nearly as possible in downstream to upstream order. The y-axis scale has been adjusted to be consistent on a regional basis to highlight differences in salinity range among geographically similar locations.

F. Observations

After the initial runs, approximately thirty salinity runs were required to adequately simulate the salinity field from the Golden Gate boundary to Carquinez Straight and Suisun Bay. We noticed two phenomena at work: First, the rebound in field surface zone salinity data during the winter months after storm events was not tracked well by the model in San Francisco Bay and Carquinez Straight (see for example the Martinez panel [Figure 19] between February and May 1993). Second, and perhaps related, model salinity does not increase in the late spring as quickly as field surface salinity. However, later in the summer, model salinity tends to overtake field salinity and peak at a slightly higher level (see for example the Martinez panel [Figure 19] between June and October in each year). Both tendencies led us to re-examine the Bay bathymetry data and ultimately to a 25% South Bay and San Pablo Bay volume decrease which appeared to be warranted by the data. Dispersion coefficients were also adjusted upward. The goal was to mix salt more quickly in to the system after storm events and in general after the wet season.

We believe that these general trends reflect a limitation of the one dimensional model. In reality there is salinity stratification in the Bay, especially during high outflow periods. One dimensional models do not simulate density stratification. Rather, the salinity field is compressed, something like an accordion, against the constant ocean boundary salinity. In reality when the hydrograph recedes, there is significant bottom salinity intrusion in the deep channels of the Bay that is immediately available to mix up into the water column. One dimensional models may artificially over-freshen the volume of San Francisco Bay during wet periods. On the subsequent receding hydrograph, there is much more volume to salinize than is required in the prototype.

Early salinity calibration runs showed that errors in matching salinity downstream tended to propagate upstream with the same pattern.

VII. Recommendations for Further Work

The recalibration effort documented in this report represents a significant improvement in the accuracy of the DSM1 model. However, numerical modeling of complex hydrodynamic systems can always be improved as numerical formulations advance and field data are collected. We suggest that a modeling team, with representatives from agencies interested in modeling efficacy should be maintained. The team should provide peer review of agency modeling efforts and guide resource allocation decisions intended for model improvements. The IEP Delta Model Project Work Team is currently serving this role. We offer the following recommendations for further work as time and resources permit.

A. Verify the DSM1 Model

A formal verification of the model has not been conducted. Ideally, numerical models are calibrated against a portion of the available data, and verified against an independent set of field data to show that the model is not over determined by the calibration data set.

The hydrodynamics calibration was conducted using three, two week periods. Taken together, the hydrodynamics module was calibrated against a range of inflow, exports and structural configurations. While a formal verification of the hydrodynamics module will be conducted in the near future, we feel confident that the range of conditions used for the calibration guards against over determination in the interim.

The salinity calibration was conducted over a contiguous three year period which includes a wet year (1993) bracketed by two dry years (1992 and 1994). By applying the model to such an extensive period of historical hydrology, the calibration is thought to be robust enough for production usage. As time permits, a nine-year historical verification will be performed by the Suisun Marsh Planning Section. In the interim, we believe the current calibration is sufficient considering the range of hydrological and operational conditions faced by the model.

B. Calibrate Suisun Marsh Hydrodynamics and Salinity

In the interest of time, the Suisun Marsh was not extensively calibrated for flow or salinity response. We are encouraged that the preliminary stage and salinity responses are good, a situation we attribute to the improved geometry description. As a primary tool for planning and analysis of Suisun Marsh programs, the Suisun Marsh Planning team considers adequate calibration and verification of the Marsh a near-term priority.

C. Monitor Connection Channels Between the Sacramento and San Joaquin Rivers

Tidal flow and salinity in the western Delta is sensitive to the geometry of Three Mile Slough, Sherman Lake, and Broad Slough. Recently, much attention has been given to Three Mile Slough geometry and flow measurement which we agree with. Sensitivity analysis on the relatively uncertain geometry of Sherman Lake and Broad Slough indicates that these connections are important energy and mixing conduits. Emphasis should be put on these locations in future bathymetric and flow measurement surveys.

D. Measure Frank's Tract Geometry

Due to it's size and central location, Frank's Tract may play an important role in buffering flow and salinity in the central Delta. Field data suggests that tidal day average salinity concentrations are rather level in the area just east and south of Frank's Tract. Sensitivity analysis with the model suggests that modification of Frank's Tract geometry, especially with regard to the geometry of openings in Frank's Tract levies, has a significant impact on area salinity. Emphasis should be put on Frank's Tract geometry in future bathymetric surveys.

E. Use Sacramento River Boundary Salinity

Future calibrations would benefit from obtaining historical salinity data for the upstream boundary. It may be necessary to use Green's Landing as a surrogate since salinity data at Sacramento is not routinely collected. In this calibration, a constant 100 parts per million TDS was assumed. Salinity at Steamboat Slough and Walnut Grove (Figure 22) indicates that Sacramento salinity can vary between about 80 and 130 mg/l TDS. We believe that

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this would improve results in the North Delta area and some insight into source water contributions would be available for stations further downstream.

F. Compare Cross-section Average and Point Salinity Data

The Annual Report to the SWRCB by the Delta Modeling Section of the Office of SWP Planning suggests that there should be an investigation of cross-section salinity variability compared to the point measurement that is routinely collected. As an example, the San Andreas salinity monitoring station consistently records lower salinity than models predict. Since the data are collected one meter below the surface near the shore of a shoaled area, and the Mokelumne River joins the San Joaquin River just upstream, it is possible that the cross-section average salinity computed by the model would consistently deviate from the point salinity data.

G. Collect Accurate Clifton Court Forebay Gate Operations Data

The intake structure at Clifton Court Forebay consists of six radial gates that are operated on a tidal basis to pump water into to the forebay. Gate operation times are input to the model. Currently, gate operation data are collected as date and time of gate opening or closing. In reality, the six gates are operated independently to regulate flows into the forebay. We suggest that gate operation data should be collected independently for each radial gate. The model would require some modification to handle the more complex operation. However, given the importance of this structure to water levels and export opportunities, accurate simulation is essential.

H. Re-survey the Delta

The bathymetry database used for the geometry revision is extensive, containing over 400,000 point coordinates. However, much of the data are outdated, some up to sixty years. While a moveable bed is a physical feature of the system, a more up-to-date data set would likely improve the accuracy of the model. The experience of various modeling groups working on the Bay-Delta system indicates that accurate geometry is an essential precursor of accurate models. An effort to re-survey Suisun Bay is under consideration at the USGS. An extension of this effort to the Delta, Suisun Marsh, and San Francisco Bay should be considered.

VIII. Merging Versions

As stated in the introduction, a goal of this project was to make calibration and geometry improvements amenable to other versions of the DSM1 model, primarily the version of DSM1 used by DWR's Delta Modeling Section within the Office of SWP Planning. A two step approach was identified to merge the versions:

A. Make code and geometry input file changes
B. Run the Delta Modeling Section version of the code with the new geometry and calibration coefficients.

A. Make code and geometry input file modifications

The geometry revision project resulted in minor modifications to the geometry input file format. Channel depth is no longer an explicit input. Rather, hydraulic depth (H_0) is calculated as area divided by top-width (A/T). Suisun Marsh Planning reformatted the new geometry file format to look like the old format using an intermediate reformatting program. Additionally, the channel length column of the geometry input file is input in feet precisely as measured. The old version expected a rounded distance written in thousands of feet. The measured distance was divided by one-thousand to accommodate the old version format. Finally, Delta gate facilities are treated somewhat differently between the versions. The Delta Modeling Section version of the "gate cards" were inserted in place of the Suisun Marsh Version format.

B. Run the Delta Modeling Section version using the new geometry

Using network connections, the Delta Modeling Section version of DSM1 was run remotely from the Suisun Marsh Planning office. Figure 24 shows the five Delta locations for which data were available in May 1994. Three traces are shown on each plot: the solid line is the Suisun Marsh version recalibration, the dashed line is the Delta Modeling Section version using the new geometry and calibration coefficients, and the dotted line is the field data. The results were identical aside from a slight phase shift between the Delta Modeling Section version and the Suisun Marsh version due to a difference in data time conventions.

D-007665

IX. Acknowledgments

DWR's Environmental Services Office, Suisun Marsh Branch completed this study with the assistance and review of staff from DWR's Division of Operations and Maintenance and Office of State Water Project Planning. Additional assistance was received from US Geological Survey staff.

X. References

1. Department of Water Resources, "Salinity Unit Conversion Equations," Memorandum, June 24, 1986.

Tables

TABLE 1
DSM1 Re-calibration geometry statistics

	Previous Calibration	CALFED Re-Calibration
Number of Channels	618	642
Number of Nodes	500	512
Number of Modified Channels	--	558
Number of Cross Sections "Surveyed"	--	1028
Number of Cross-Sections surveyed per channel	--	1 to 8
Total Length (mi)	1047	1064
Total Volume (TAF)*	8300	6501

* Volume measured from vertical datum of MLLW.

Figures

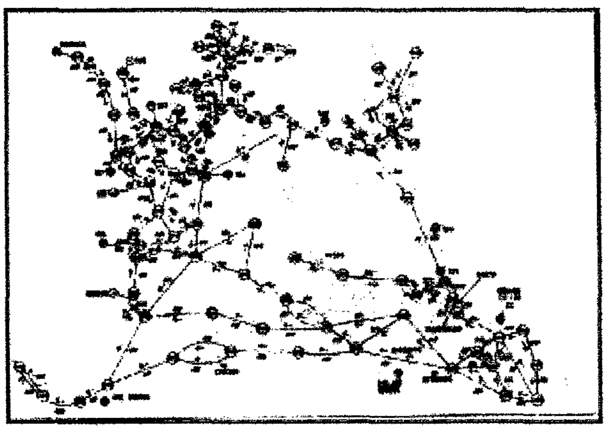
D-007670

FIGURE 1

http://www.iep.water.ca.gov/calfed/dsm1

DSM1 Suisun Marsh Version Re-calibration

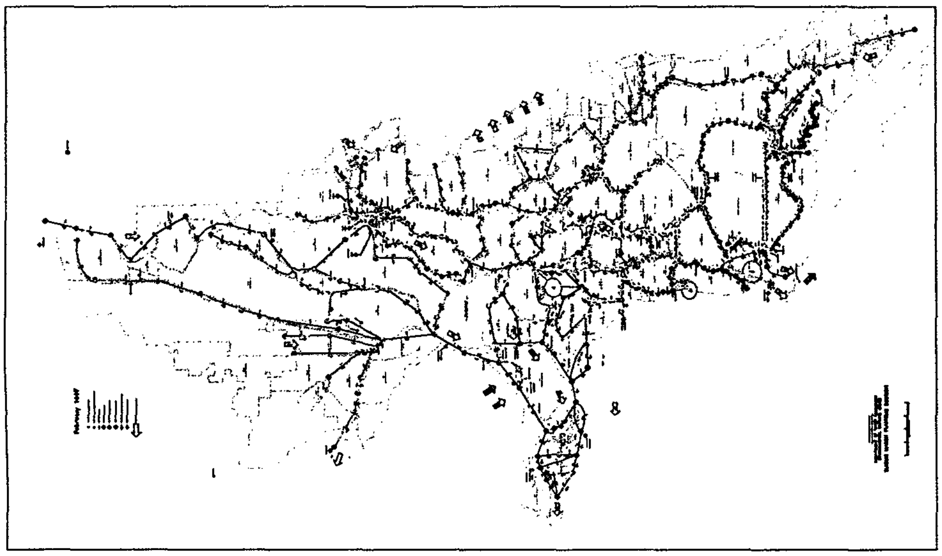
Suisun Marsh Grid Map

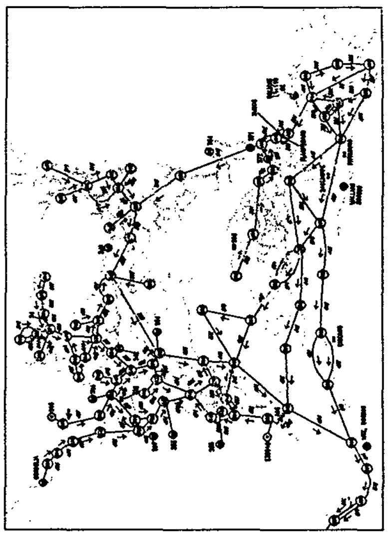


- DSM1 Hydro-calibration
  - Net Flow Splits
- DSM1 Salinity-calibration
- Manning Coefficient Groups
- Three Mile Slough Info
- Background

D-007671

FIGURE 2





GRID MAP
DWR DELTA SIMULATION MODEL
(SUISUN MARSH VERSION G9A)

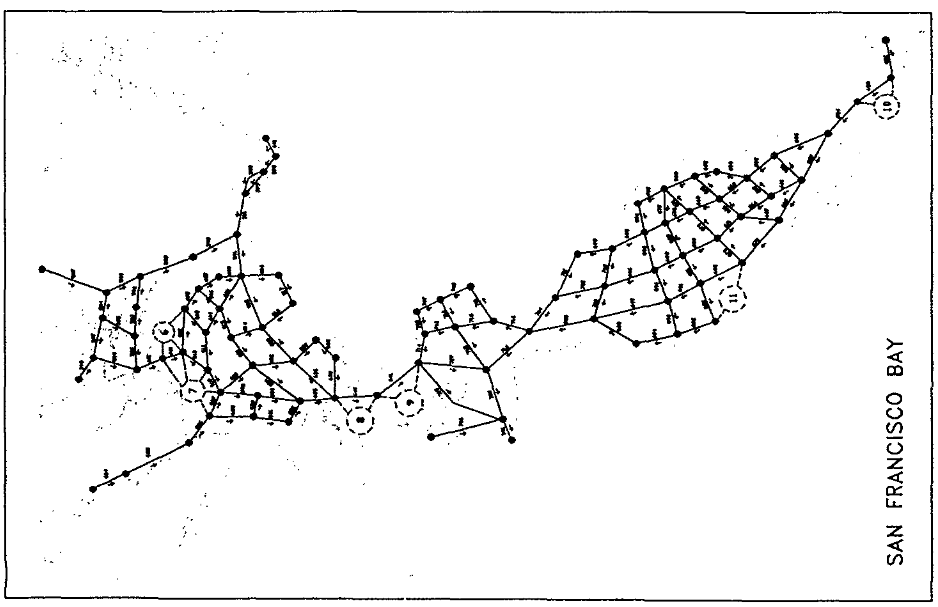
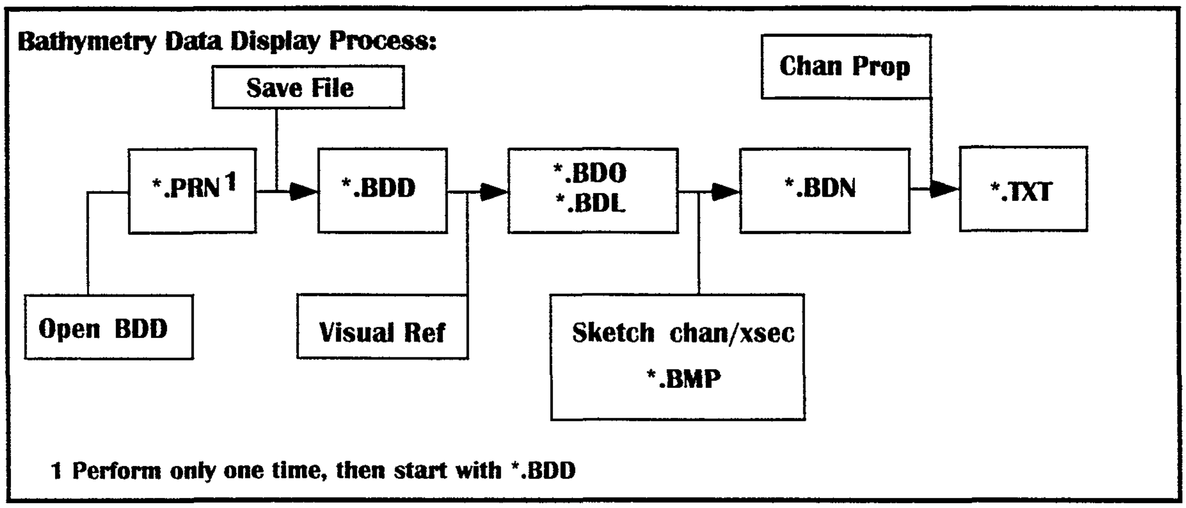
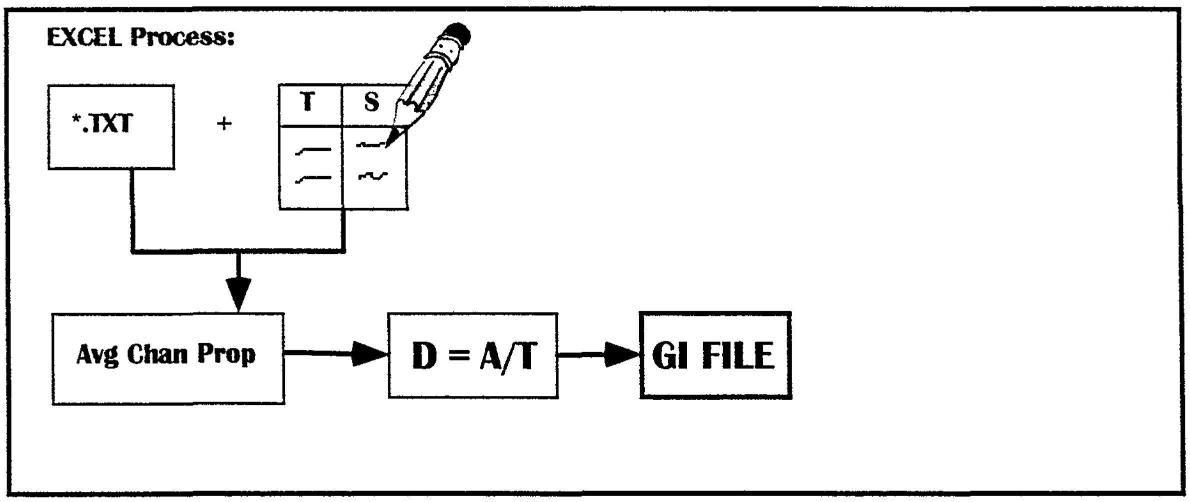


FIGURE 3

CALFED DSM1 Re-calibration
Geometry Validation Procedure





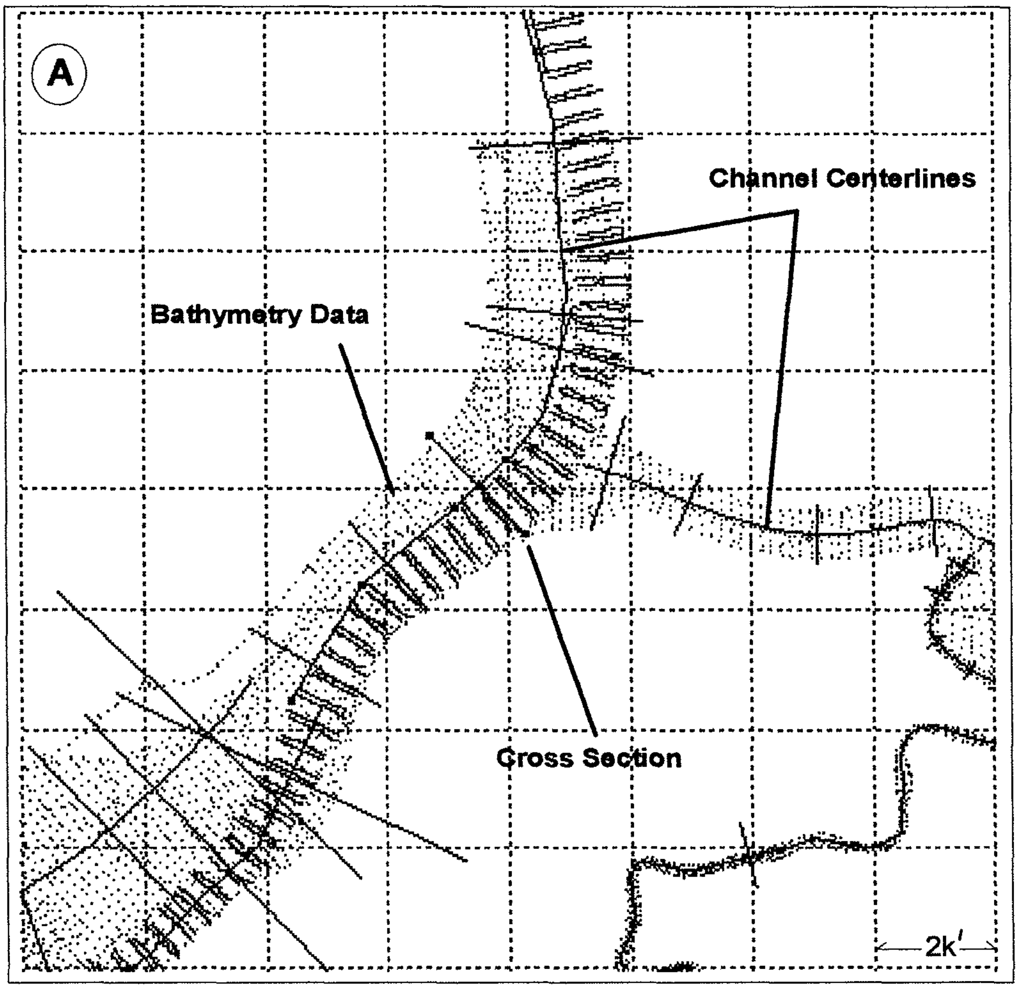
SAMPLE GI FILE:

CHAN	L[ft]	A[ft²]	T[ft]	P[ft]	SS	BS	n	D	E vs W	Comment
341	7139.	4608.	357.	362.	0.0	0.00000	0.020	0.25	F T F	BDD
342	7380.	4411.	353.	358.	0.0	0.00000	0.020	0.25	F T F	BDD
343	4443.	5038.	330.	337.	0.0	0.00000	0.020	0.25	F T F	BDD
344	7088.	6626.	435.	447.	0.0	0.00000	0.020	0.25	F T F	BDD

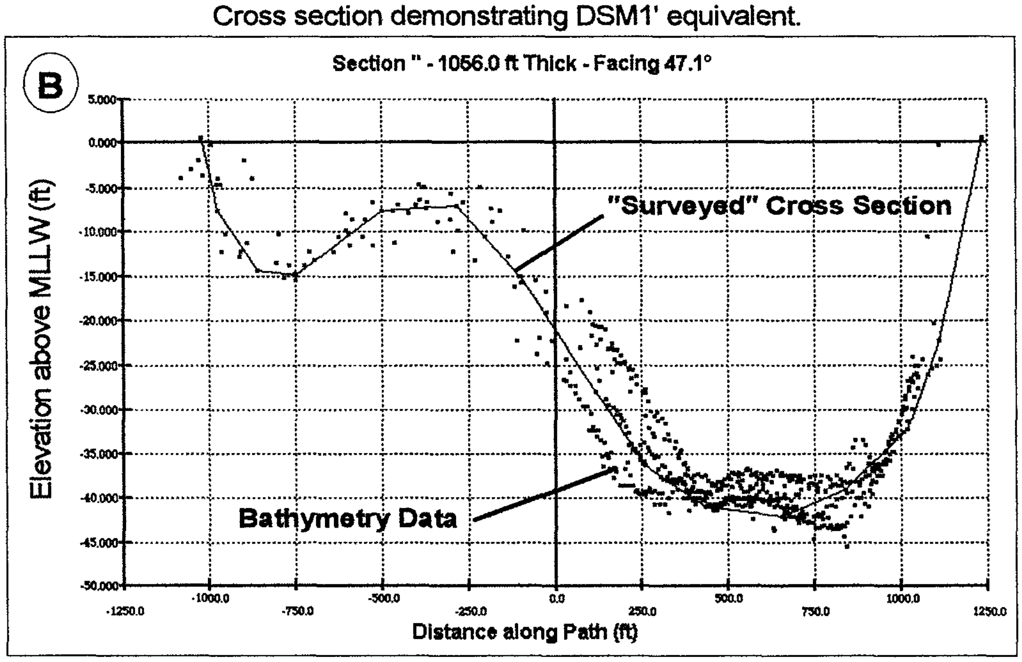
FIGURE 3

FIGURE 4

Aerial bathymetry view of San Joaquin River.



Cross section demonstrating DSM1' equivalent.



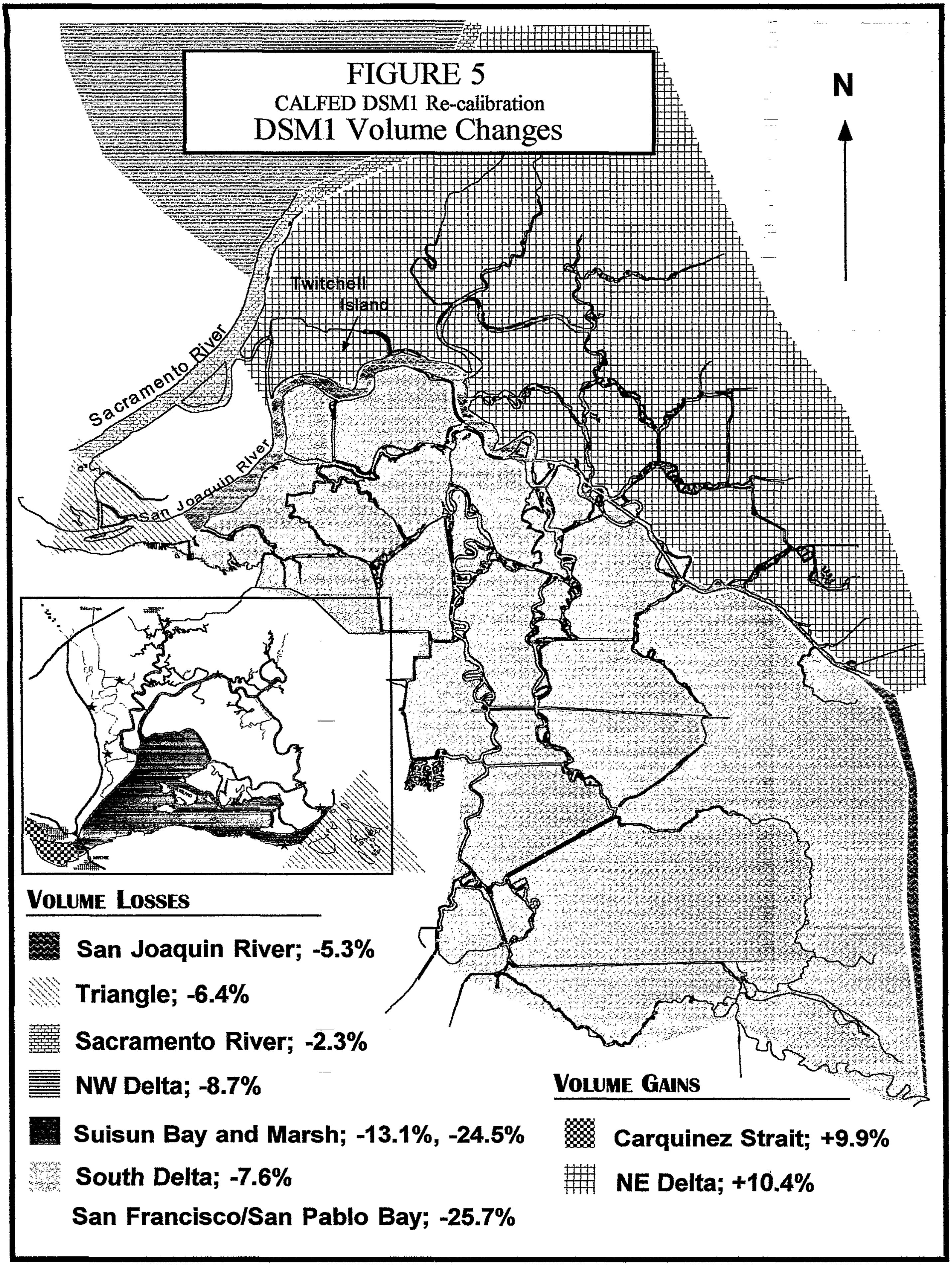
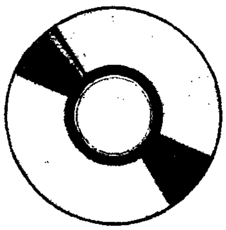


FIGURE 5
CALFED DSM1 Re-calibration
DSM1 Volume Changes
N
Twitchell Island
Sacramento River
San Joaquin River
VOLUME LOSSES
San Joaquin River; -5.3%
Triangle; -6.4%
Sacramento River; -2.3%
NW Delta; -8.7%
Suisun Bay and Marsh; -13.1%, -24.5%
South Delta; -7.6%
San Francisco/San Pablo Bay; -25.7%
VOLUME GAINS
Carquinez Strait; +9.9%
NE Delta; +10.4%

FIGURE 6

CALFED DSM1 Re-calibration Geometry Validation Procedure



Geometry Revision

- Documentation
- Bathymetry Viewer Software
- Bathymetry Data
- Cross Sections
  - Properties
  - Bitmaps
- Old DSM1 Geometry (G8A)
- New DSM1 Geometry (G9A)
- Grid Map

FIGURE 7. DSM1 sample of manning group configuration.

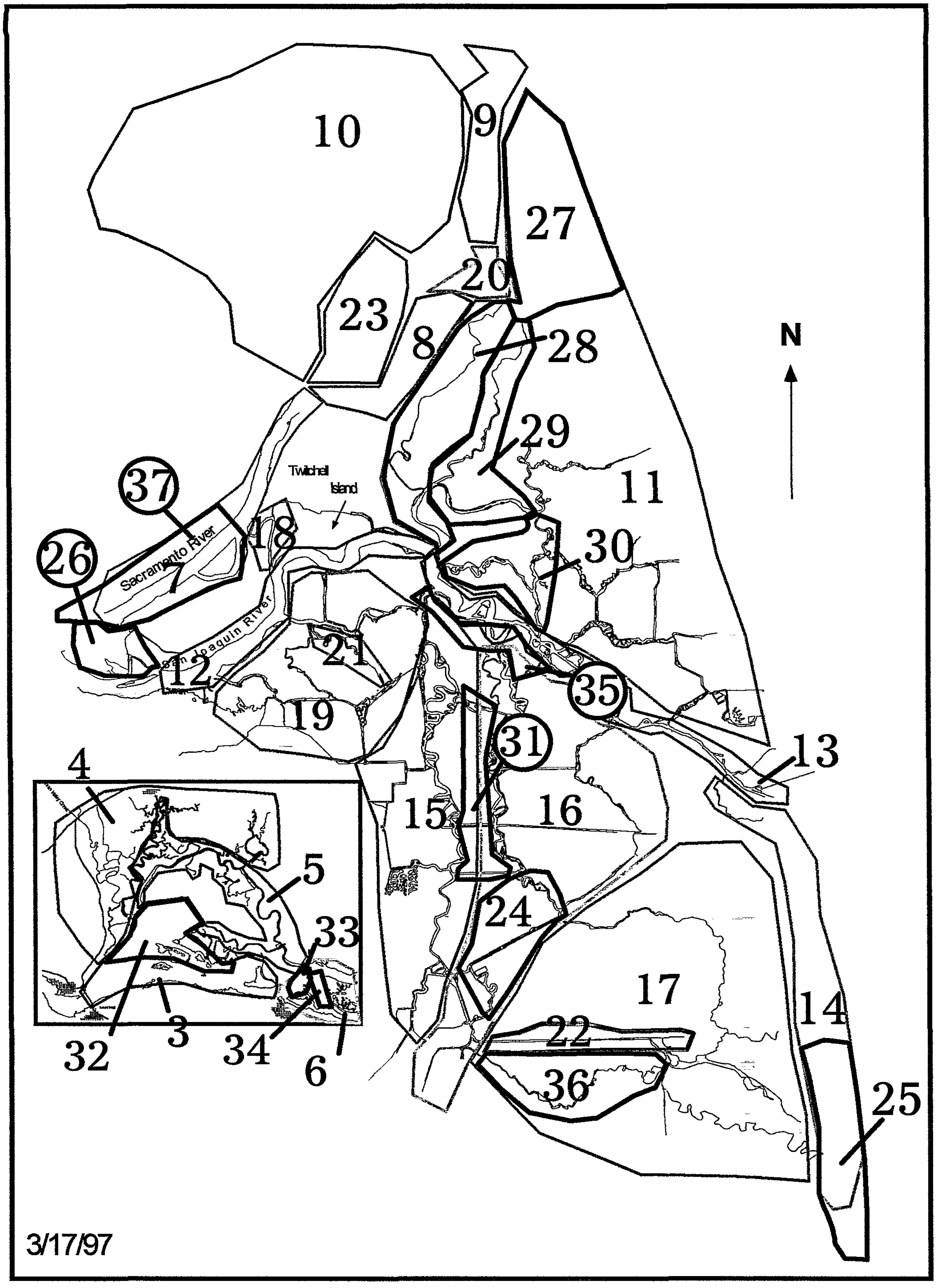


FIGURE 8

Manning's n and Dispersion Coefficients for DSM1 Calibration Groupings
Run T63; 6-18-97

```
63        ! QAL Run Number
42        ! Number of Manning's n channel groupings
42        ! Number of Dispersion coeff channel groupings
---------- Manning's n Groups ------------------------------------------------------------------
  1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20
.015 .018 .018 .035 .030 .021 .025 .030 .025 .030 .026 .024 .022 .022 .024 .034 .031 .018 .028 .031

 21   22   23   24   25   26   27   28   29   30   31   32   33   34   35   36   37   38   39   40
.022 .022 .026 .026 .031 .035 .031 .025 .025 .026 .025 .029 .035 .025 .035 .027 .021 .015 .015 .020

 41   42   43   44   45   46   47   48   49   50   51   52   53   54   55   56   57   58   59   60
.018 .024
----------- Dispersion Coefficient Groups ------------------------------------------------------
  1    2    3    4    5    6    7    8    9   10   11   12   13   14   15   16   17   18   19   20
1.00 0.25 0.27 0.40 0.40 0.40 0.40 0.25 0.25 0.25 0.25 0.10 0.25 0.25 0.25 0.25 0.25 0.01 0.15 0.25

 21   22   23   24   25   26   27   28   29   30   31   32   33   34   35   36   37   38   39   40
0.15 0.40 0.25 0.25 0.25 0.01 0.25 0.25 0.25 0.25 0.25 0.40 0.30 0.01 0.25 0.70 0.40 4.00 0.25 0.10

 41   42   43   44   45   46   47   48   49   50   51   52   53   54   55   56   57   58   59   60
0.20 0.50
------------------------------------------------------------------------------------------------
```

Run T63: HYDRO and SALINITY:
        1) re-run T60 to get all FP files for May & June 1994

Run T62: HYDRO and SALINITY:
        1) decrease n in Three Mile Slough to 0.005 from 0.018

Run T61: Salinity Only;
        1) New Group: G42; Increase D in Indian Sl to 0.5 from .25
        2) Increase D in Old River at DMC (G36) to 0.7 from 0.4

Run T60: HYDRO and SALINITY RUN
        1) run to generate tides for further salinity calibration after
           testing Three Mile and New York Slough Manning's n sensitivity.

Run T59: HYDRO and SALINITY RUN (based on R97 Manning's. T57 Dispersion)
        1) TEST: increase n in Three Mile Sl to 0.10

Run T58: HYDRO AND SALINITY RUN (based on R97 Manning's, T57 Dispersion)
        1) Test: increase n in New York Slough to 0.10

Run T57: Based on T55; Turn off dynamic ag drain routine.

Run T56: Based on T55; Increase Emmaton-Rio Vista to 0.4 from 0.3

Run T55: Based on T54; include channels 570 and 443 in CI/Spoonbill (G41)

Run T54: Based on T53; Error corrected output locations (Jersey Point further upstream)

Run T53: New dispersion group: G41; c437 and c442 at Chipps Is. Set D = 0.20
        This run also includes a correction of New York Sl D which is reduced
        for the first time in this run *actually* to 0.1 from 0.25

Run T52: Based on Run T50
        1) Reduce D in Broad Sl, Sherman Lake and Three Mile to 0.01

FIGURE 9

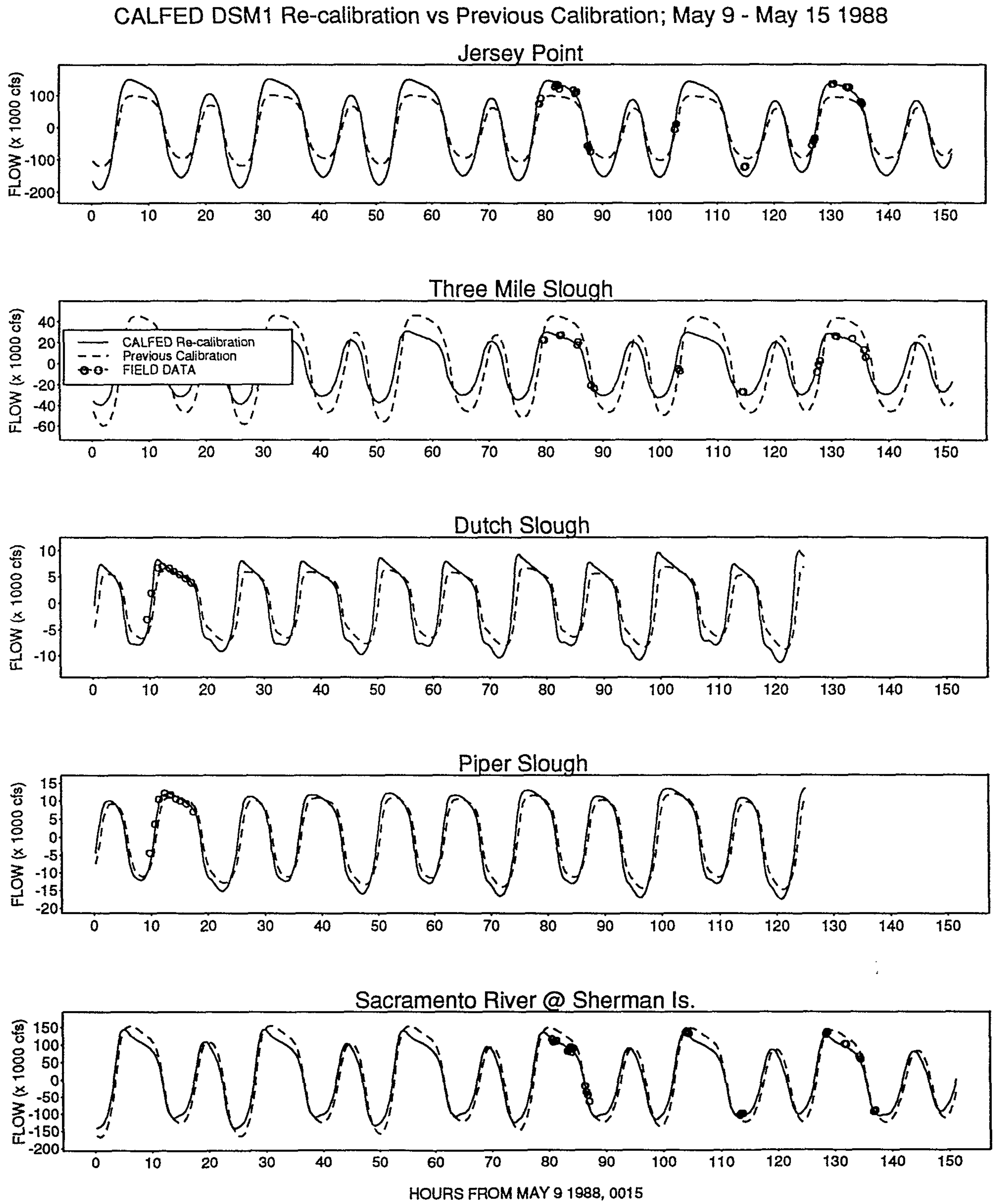
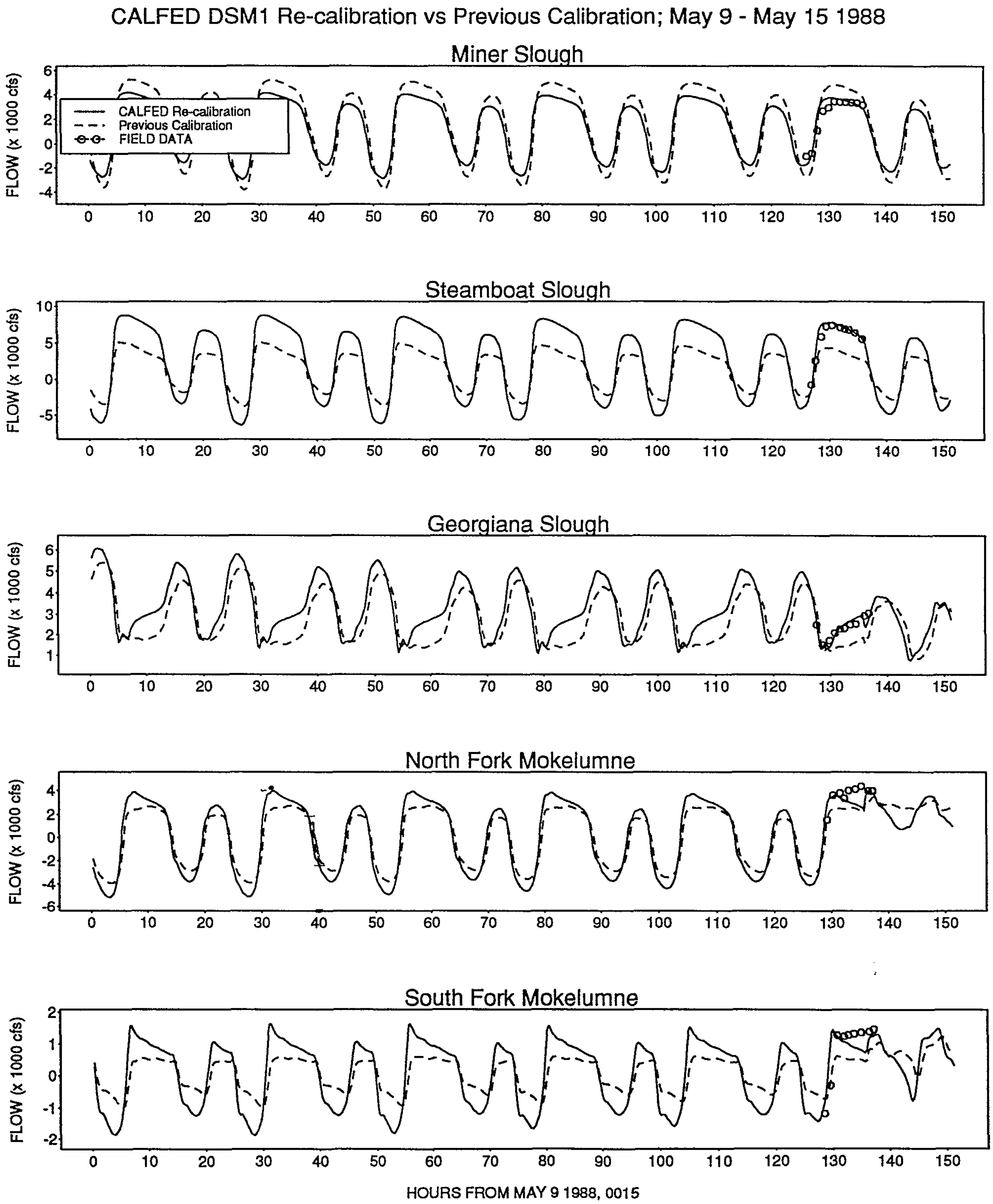
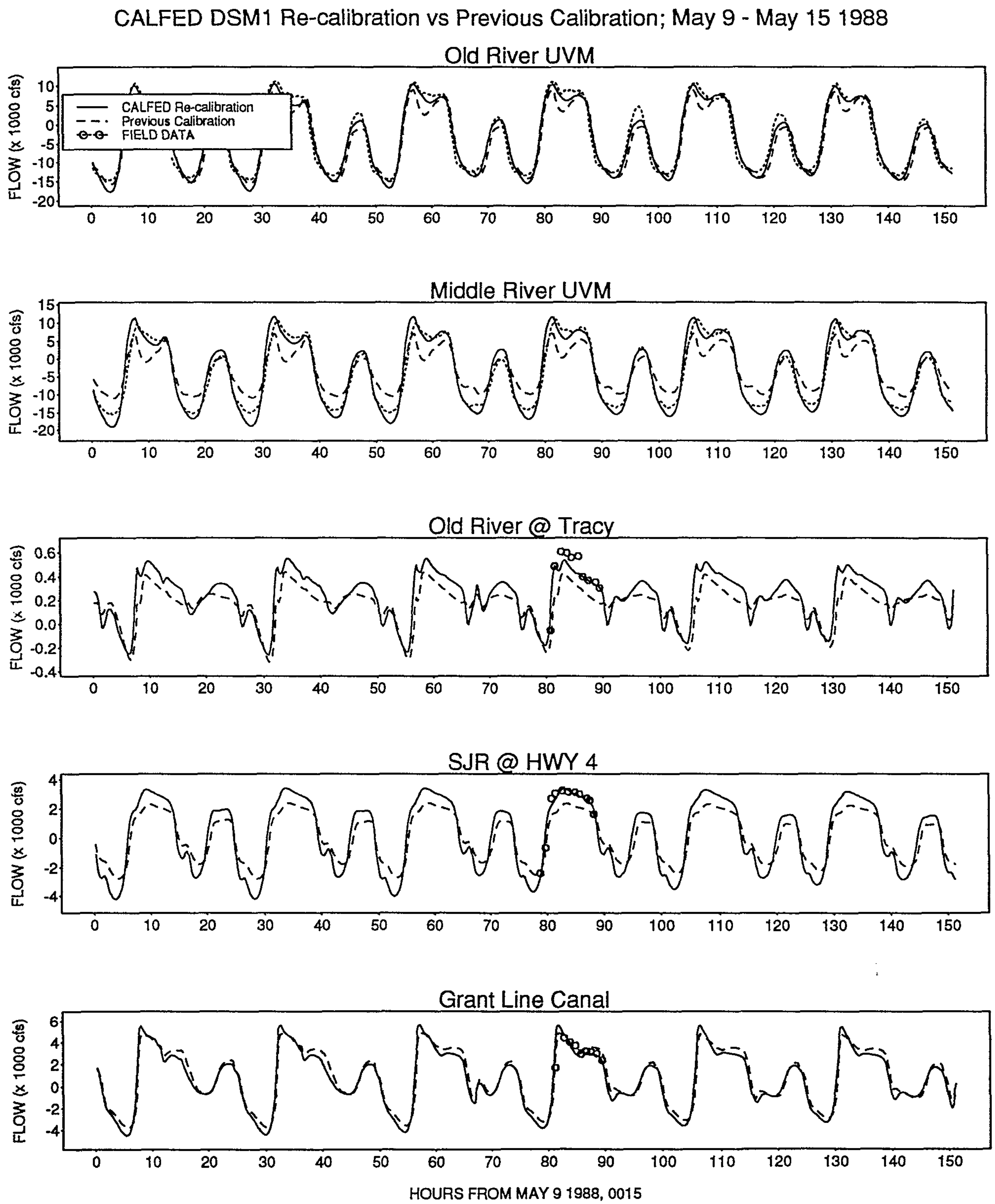

CALFED DSM1 Re-calibration vs Previous Calibration; May 9 - May 15 1988
Jersey Point
Three Mile Slough
Dutch Slough
Piper Slough
Sacramento River @ Sherman Is.
FLOW (x 1000 cfs)
CALFED Re-calibration
Previous Calibration
FIELD DATA
HOURS FROM MAY 9 1988, 0015

FIGURE 10



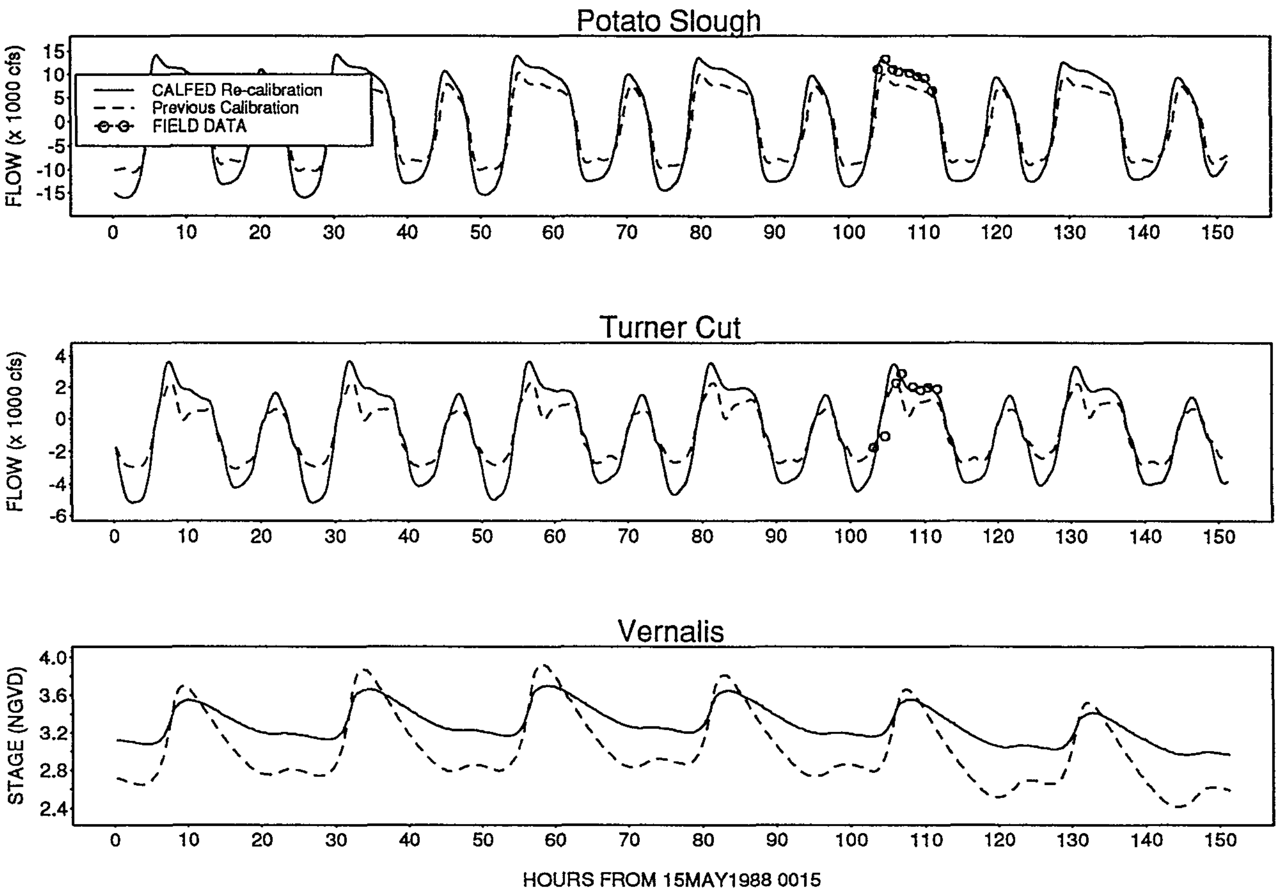
D-007681

FIGURE 11



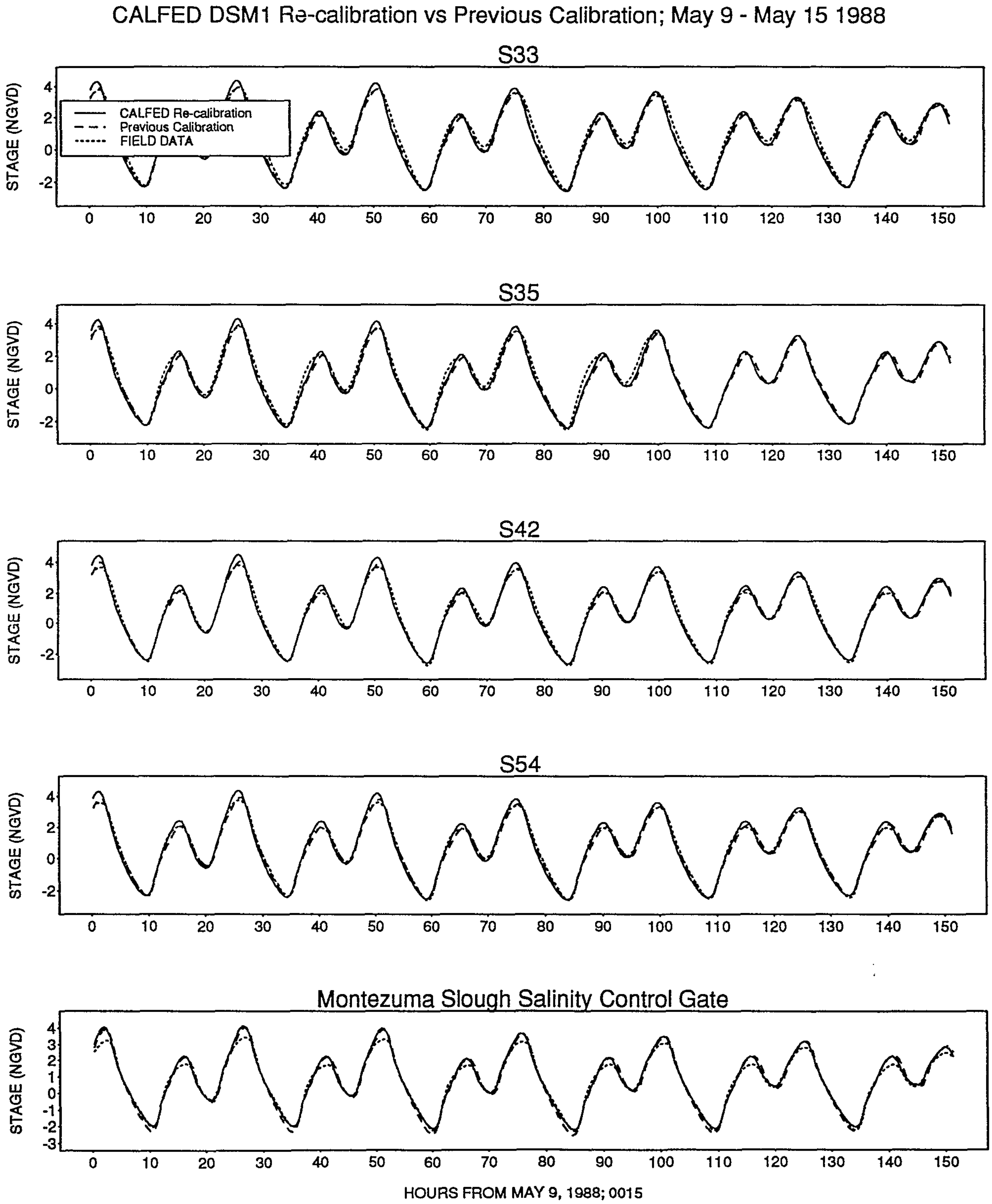
D-007682

FIGURE 12



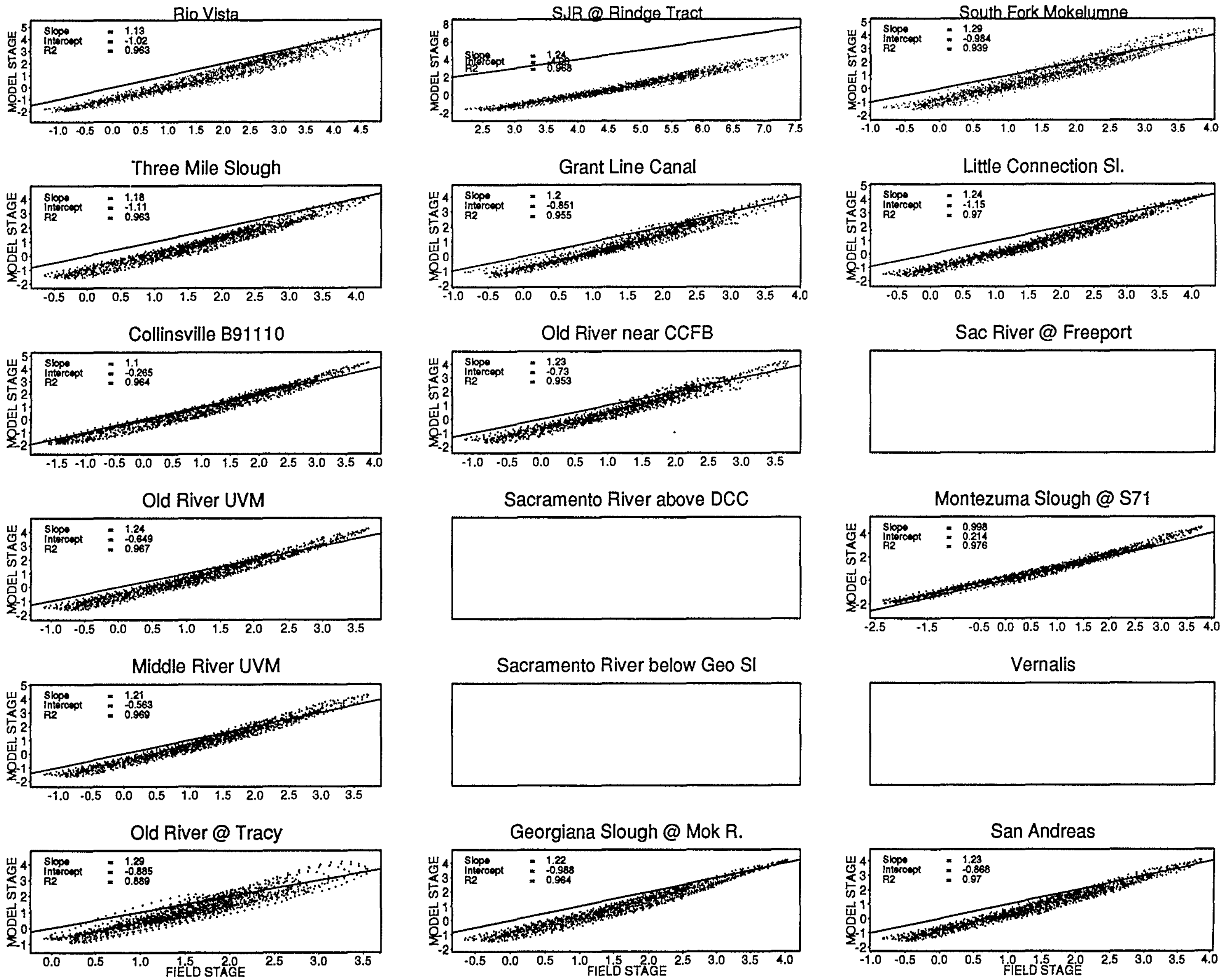
Potato Slough
FLOW (x 1000 cfs)
15
10
5
0
-5
-10
-15
CALFED Re-calibration
Previous Calibration
FIELD DATA
Turner Cut
FLOW (x 1000 cfs)
4
2
0
-2
-4
-6
Vernalis
STAGE (NGVD)
4.0
3.6
3.2
2.8
2.4
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
HOURS FROM 15MAY1988 0015

FIGURE 13



D-007684

MAY 15 - JUN 01 1994; DSM Suisun Marsh Version *RUN T01* Page 1



Thu Aug 21 09 46 22 PDT 1997

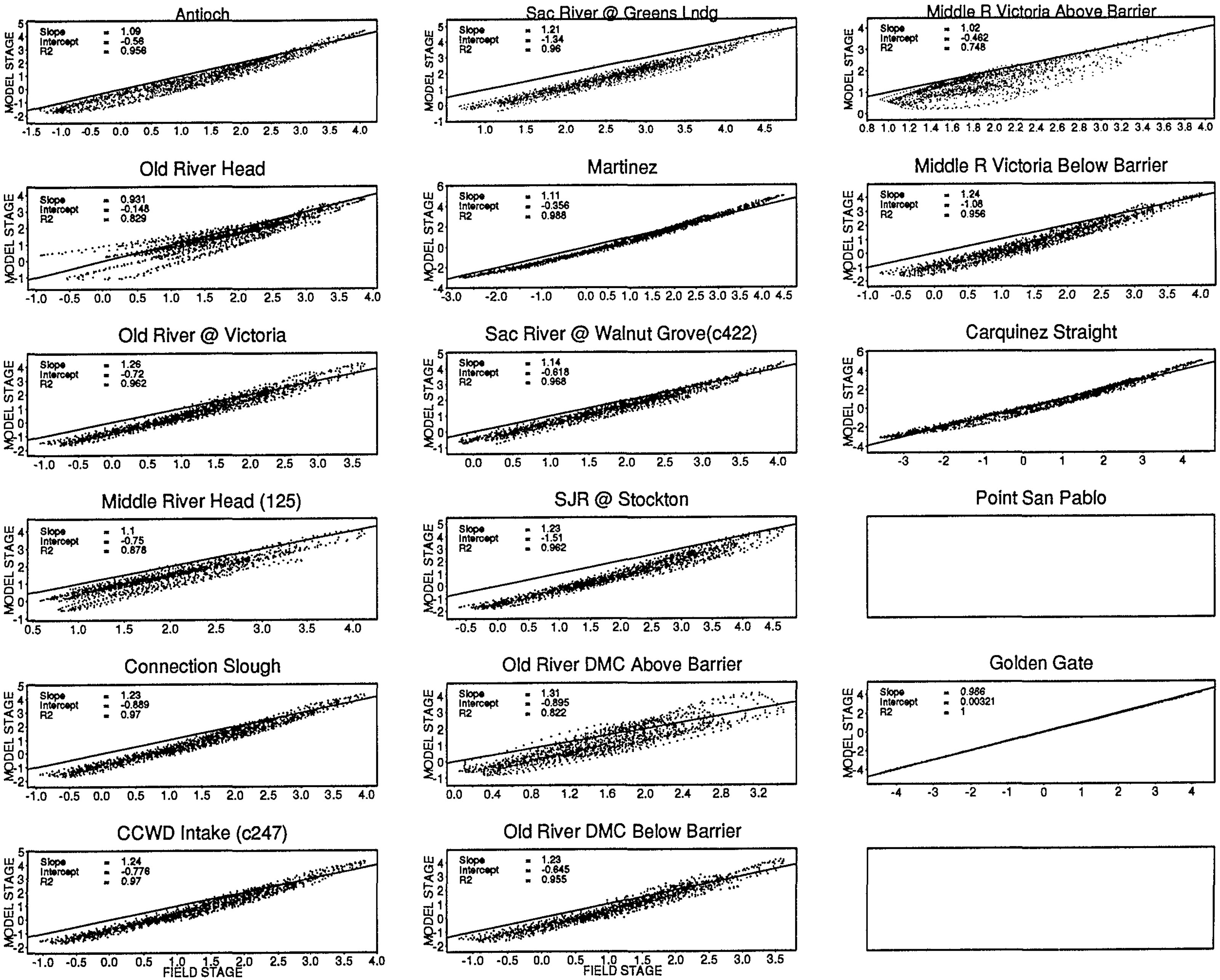
DWR SUISUN MARSH MODELING (DRAFT)

FIGURE 14

D-007685

D-007686

MAY 15 - JUN 01 1994; DSM Suisun Marsh Version *RUN T01* Page 2



Thu Aug 21 09:49:04 PDT 1997

WR SUISUN MARSH MODELING (DRAFT)

FIGURE 15

D—007686

MAY 15 - JUN 01 1994; DSM Suisun Marsh Version *RUN T01* Page 3

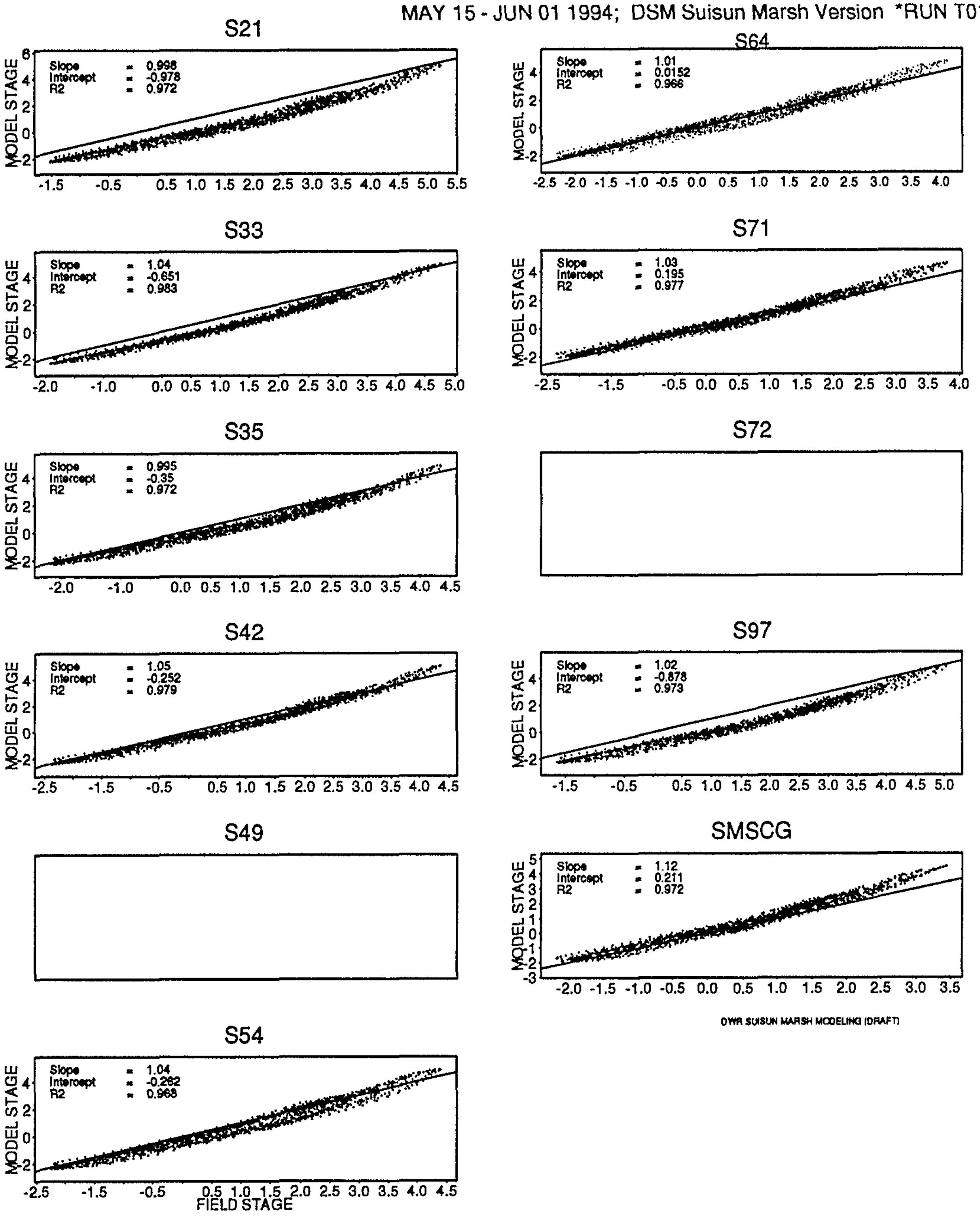


FIGURE 16

D-007687

D-007687

** RUN33 vs RUN32 ** WY 1994 Tidal Day Average Flow (24.75 hr) 4/11/97

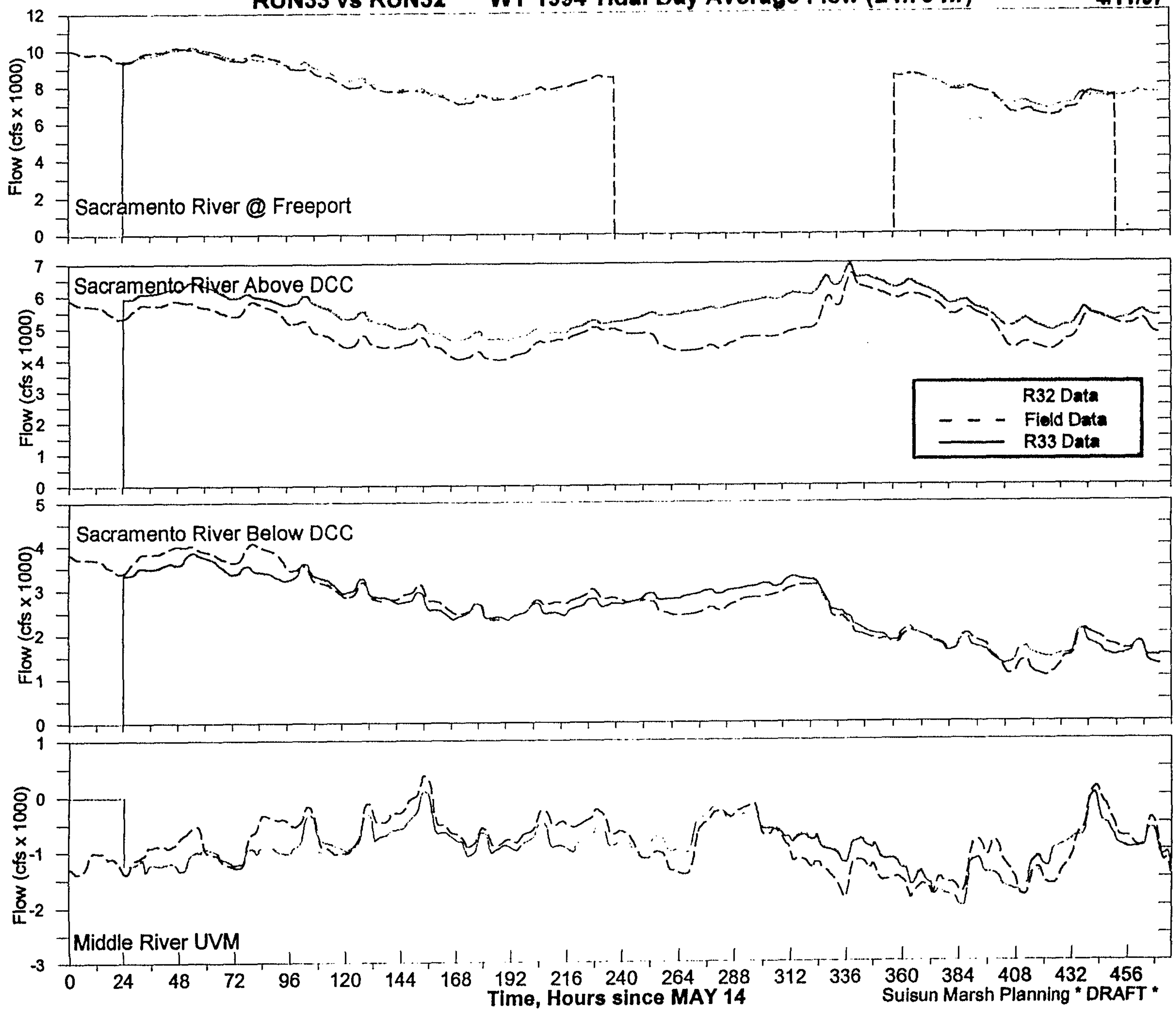


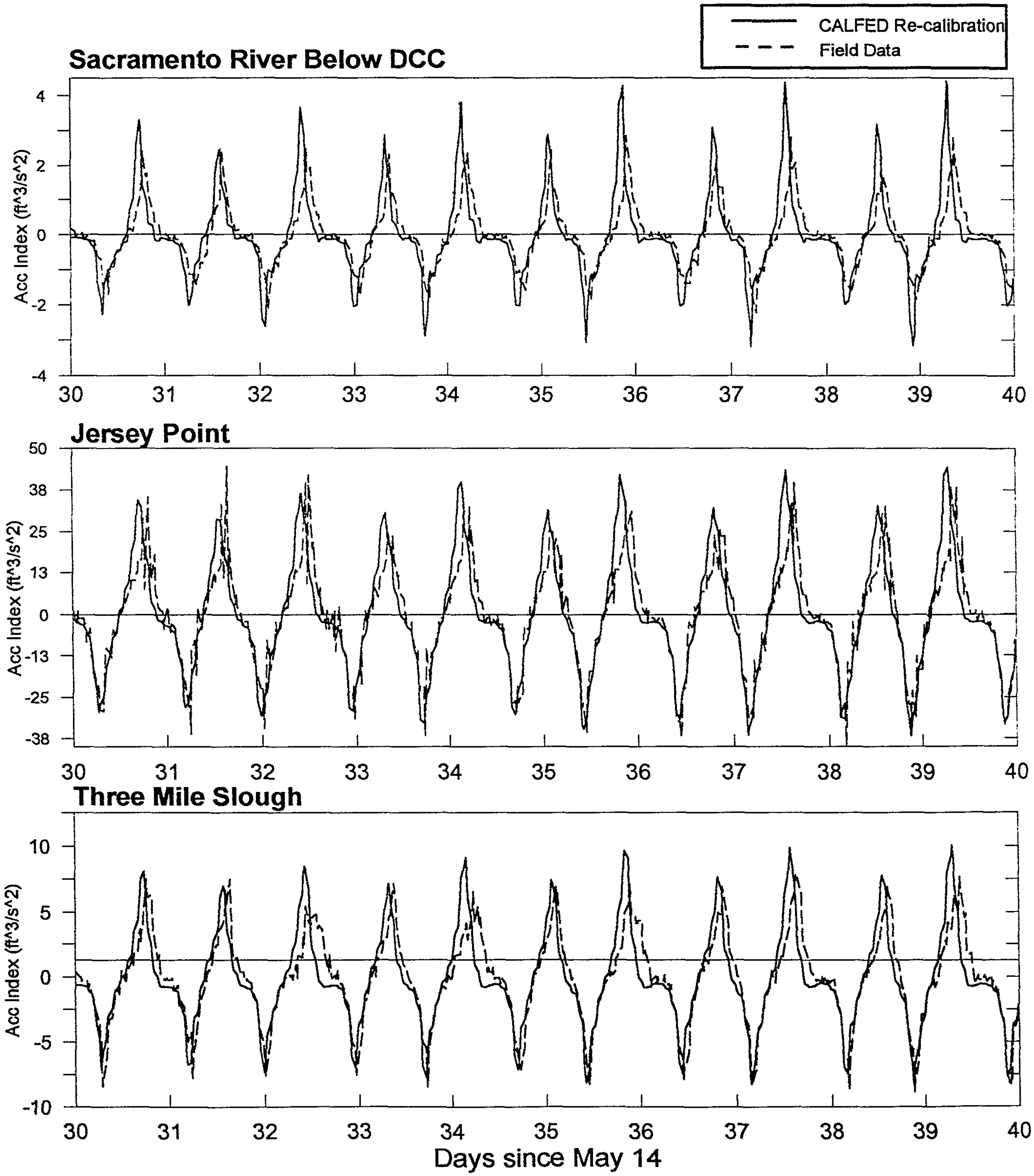
FIGURE 17

D—007688

FIGURE 18

** CALFED Re-calibration vs Field Data **

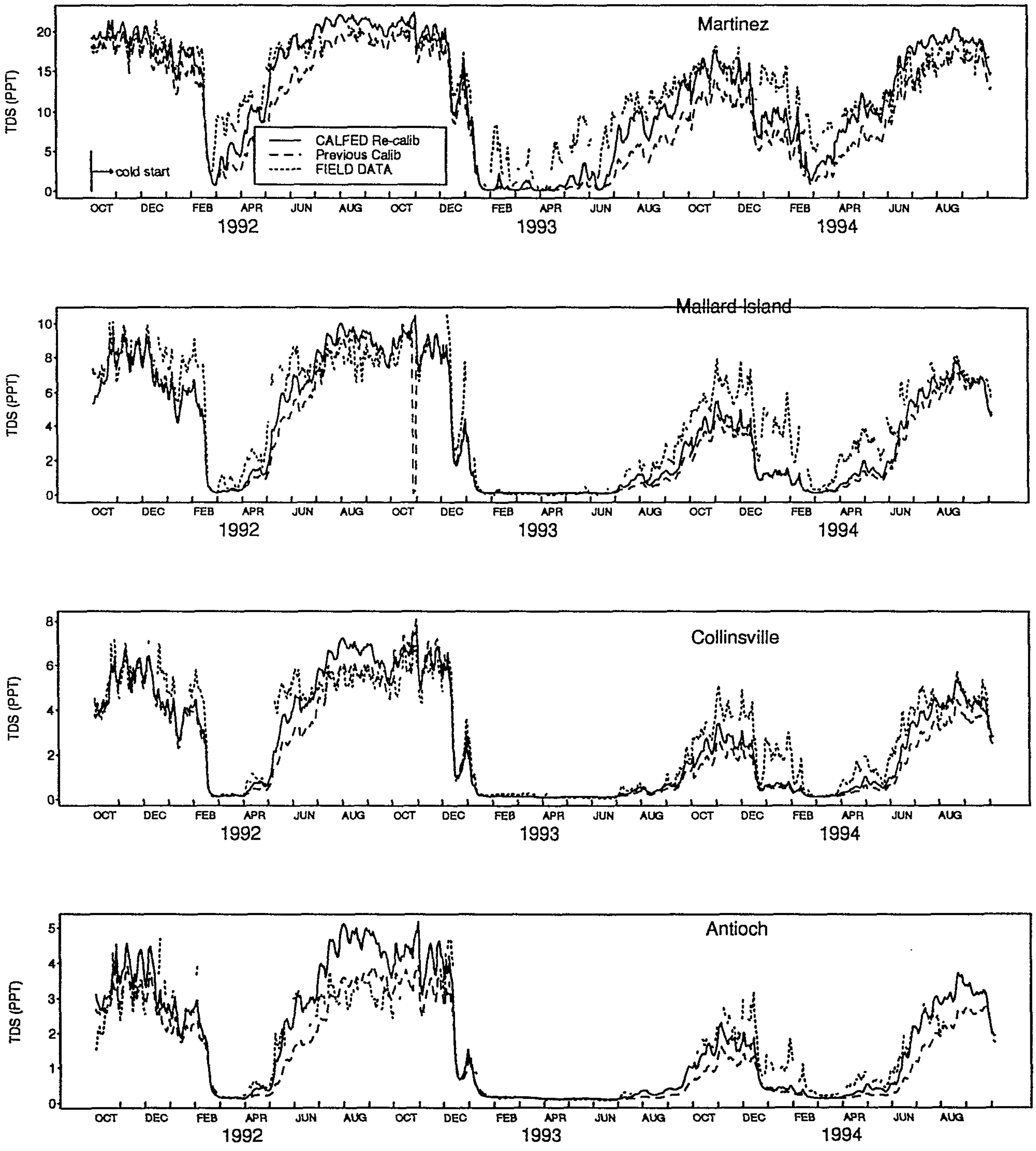
May 1994 Acceleration Index



D −0 0 7 6 8 9

FIGURE 19

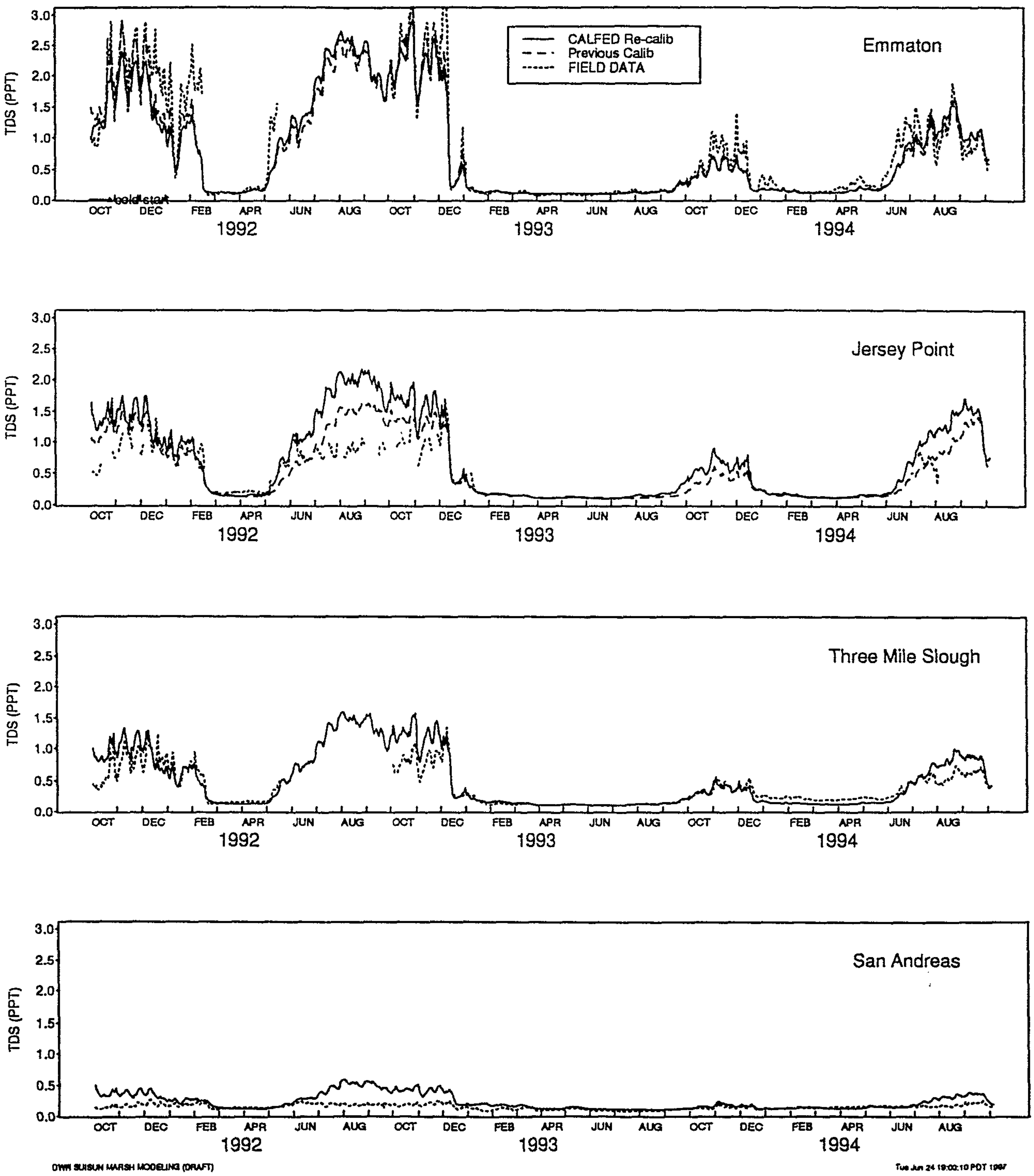
DSM1 Suisun Marsh Version Re-calibration - Tidal Day Average Salinity; WATER YEARS 1992 -> 1994:
CALFED Re-calibration vs Previous Calibration: Suisun Bay/West Delta Area



D-007690

FIGURE 20

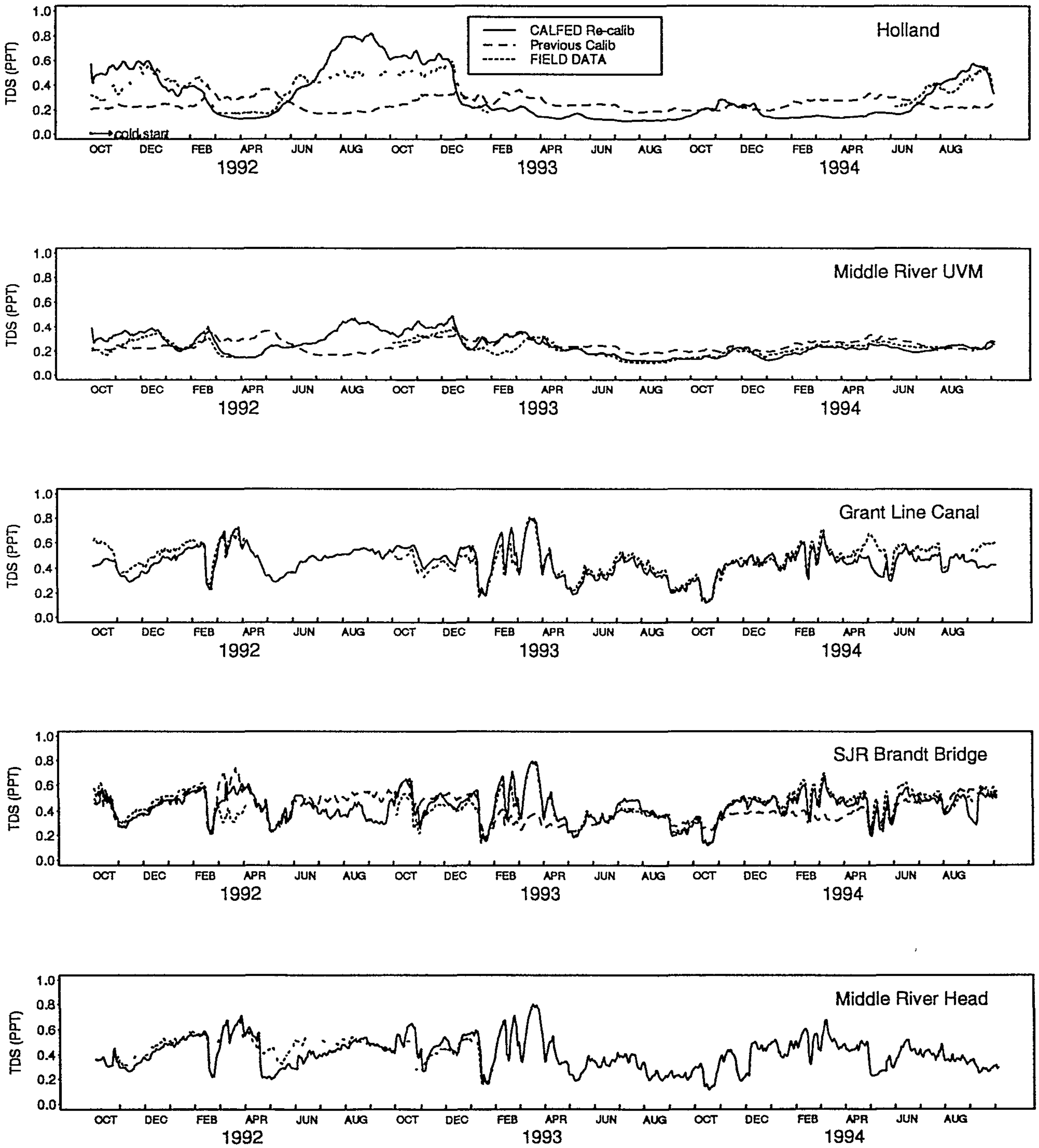
DSM1 Suisun Marsh Version Re-calibration - Tidal Day Average Salinity; WATER YEARS 1992 -> 1994:
CALFED Re-calibration vs Previous Calibration: West Delta Area



D-007691

FIGURE 21

DSM1 Suisun Marsh Version Re-calibration - Tidal Day Average Salinity; WATER YEARS 1992 -> 1994:
CALFED Re-calibration vs Previous Calibration: South Delta Area

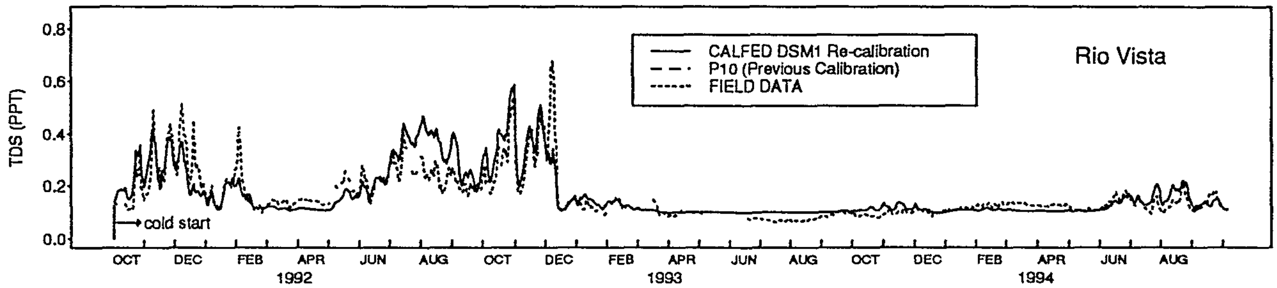


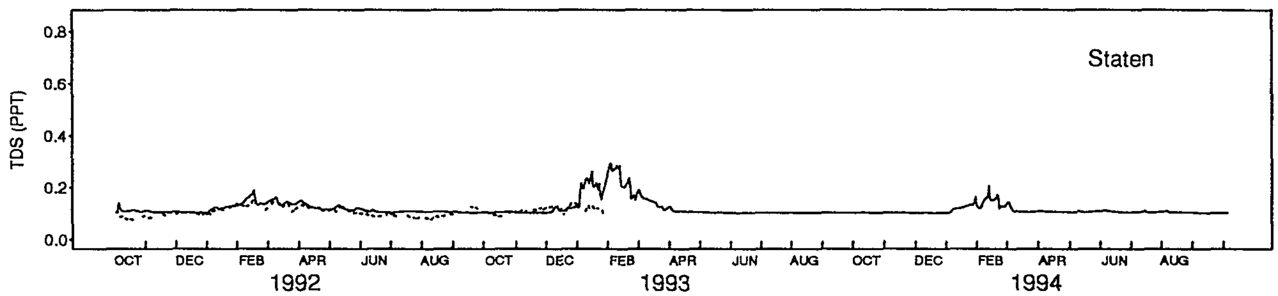
DWR SUISUN MARSH MODELING (DRAFT)

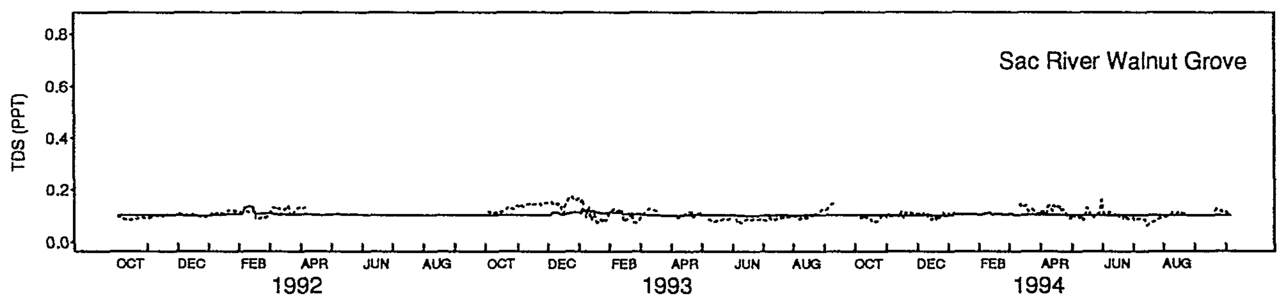
Tue Jun 24 19:00:13 PDT 1997

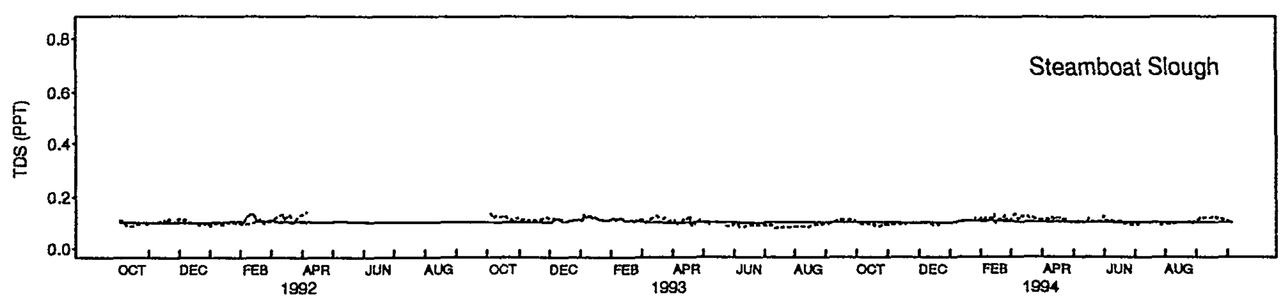
FIGURE 22

DSM1 Suisun Marsh Version Re-calibration - Tidal Day Average Salinity; WATER YEARS 1992 -> 1994:
CALFED Re-calibration vs Previous Calibration: North Delta Area







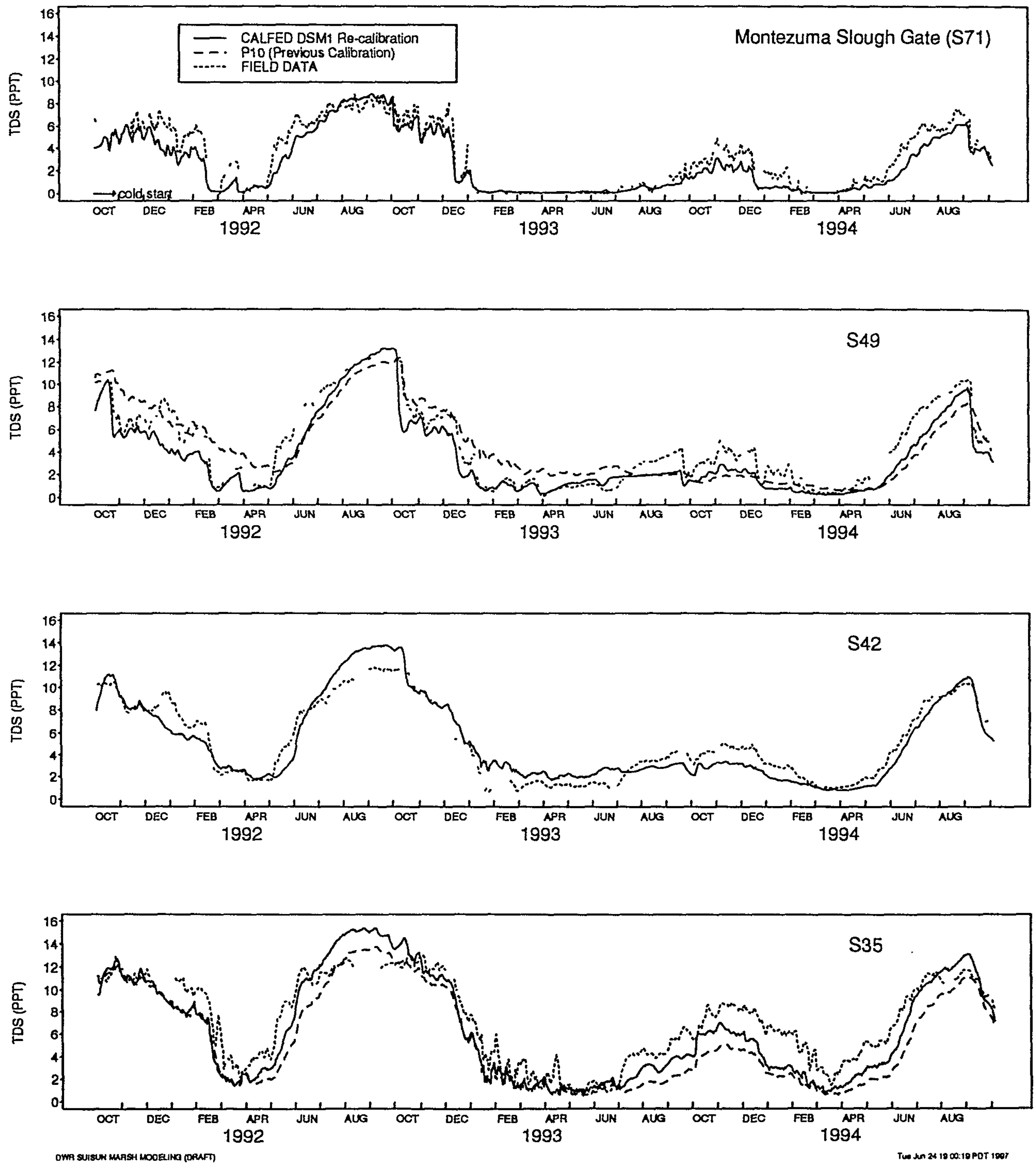


DWR SUISUN MARSH MODELING (DRAFT)

Tue Jun 24 19:00:16 PDT 1997

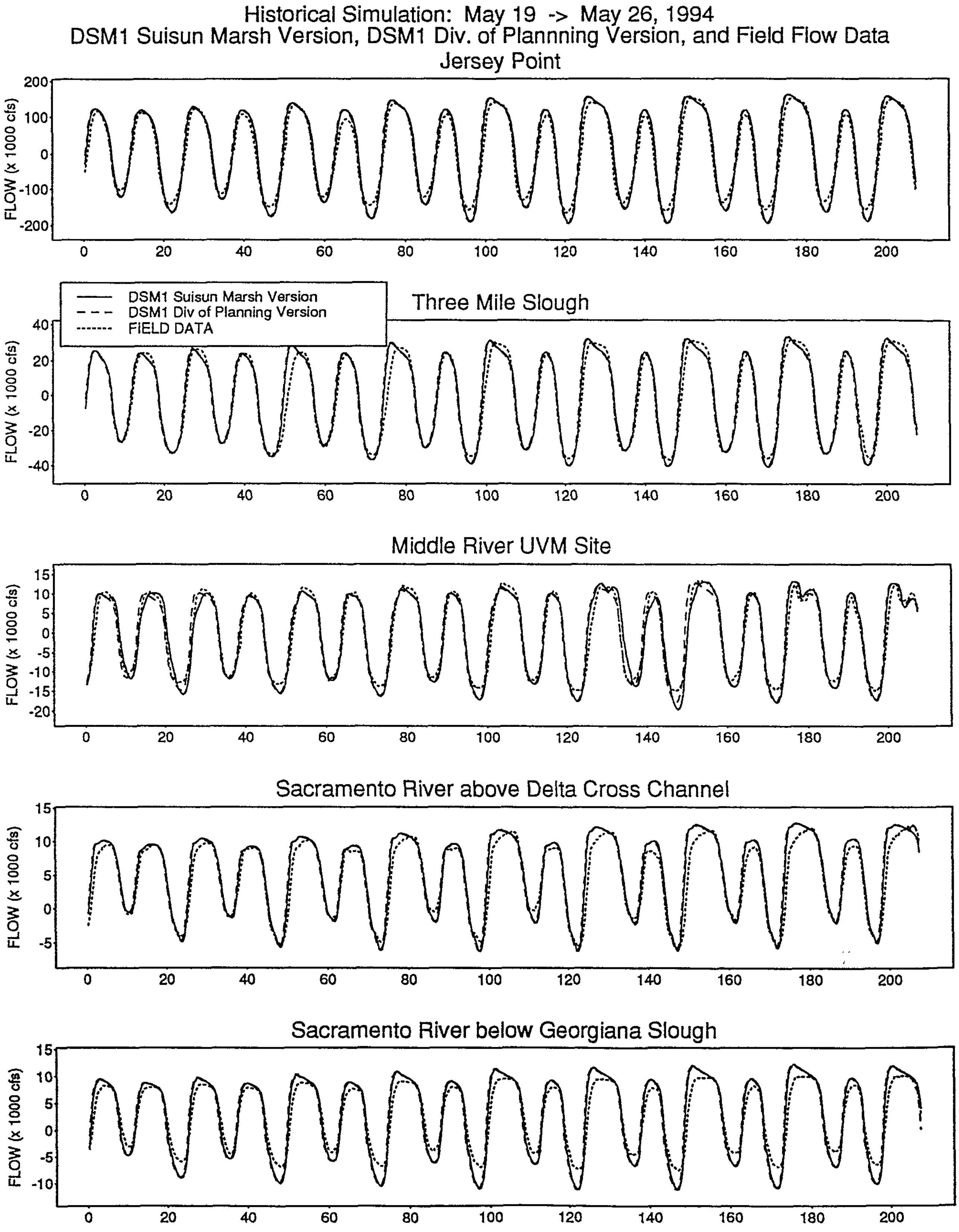
FIGURE 23

DSM1 Suisun Marsh Version Re-calibration - Tidal Day Average Salinity; WATER YEARS 1992 -> 1994:
CALFED Re-calibration vs Previous Calibration: Suisun Marsh Area



D-007694

FIGURE 24



Historical Simulation: May 19 -> May 26, 1994
DSM1 Suisun Marsh Version, DSM1 Div. of Plannning Version, and Field Flow Data
Jersey Point
FLOW (x 1000 cfs)
200
100
0
-100
-200
0 20 40 60 80 100 120 140 160 180 200
DSM1 Suisun Marsh Version
DSM1 Div of Planning Version
FIELD DATA
Three Mile Slough
FLOW (x 1000 cfs)
40
20
0
-20
-40
0 20 40 60 80 100 120 140 160 180 200
Middle River UVM Site
FLOW (x 1000 cfs)
15
10
5
0
-5
-10
-15
-20
0 20 40 60 80 100 120 140 160 180 200
Sacramento River above Delta Cross Channel
FLOW (x 1000 cfs)
15
10
5
0
-5
0 20 40 60 80 100 120 140 160 180 200
Sacramento River below Georgiana Slough
FLOW (x 1000 cfs)
15
10
5
0
-5
-10
0 20 40 60 80 100 120 140 160 180 200